RESULTS

Near-shore Survey Results

Effects of Human Activities on Long-tailed Ducks

We compared Long-tailed Duck population trends in "Industrial" and "Control" areas. We applied the combined LGL (1990-1991) and USFWS (1999-2000) data sets to ANOVA and ANCOVA models and found no significant interaction between Area and Year (ANOVA: $F_{3,12} = 1.798$, $P = 0.201$; ANCOVA: $F_{3,12} = 1.557$, $P = 0.251$; Fig. 5, Table 7). While we did not detect a disproportionate change between the areas, we did detect a significant decline in densities of Long-tailed Ducks within the study area as a whole (ANOVA: $F_{3,12} = 7.664$, $P = 0.004$; ANCOVA: $F_{3,12} = 8.716$, $P = 0.002$; Fig. 6).

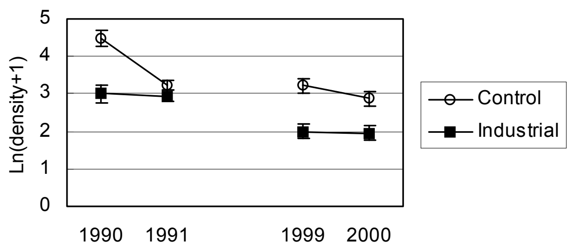

Figure 5. Comparison of trends in Long-tailed Duck log density (± 95% CI) in Control and Industrial transects. While density decreased overall, the interaction between Year and Area was not significant.

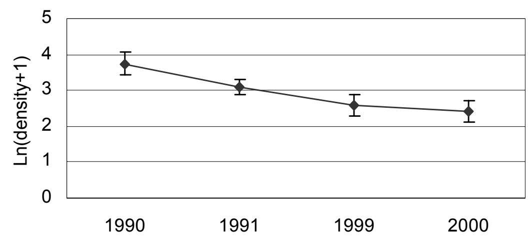

Figure 6. Long-tailed Duck log density (± 95% CI) decreased significantly within near-shore transects between 1990 and 2000.

Next, we examined the relationship between Long-tailed Duck densities and human activities by assessing the significance of the Disturbance term that indicated the degree of human activity on survey transects. We found no significant effect of Disturbance on Long-tailed Duck densities (ANOVA: $F_{2,550} = 0.812$, $P = 0.445$; ANCOVA: $F_{2,549} = 1.104$, $P = 0.332$; Table 7). A total of 171 potential disturbances in the form of boat, aerial, and land-based human activities were recorded in 1990-1991 and 1999-2000 (Table 8, Fig. 7, 8). Within the 24 transects used for analysis, potential disturbances occurred at a rate of 2.5 in Industrial transects to every 1 on Control transects.

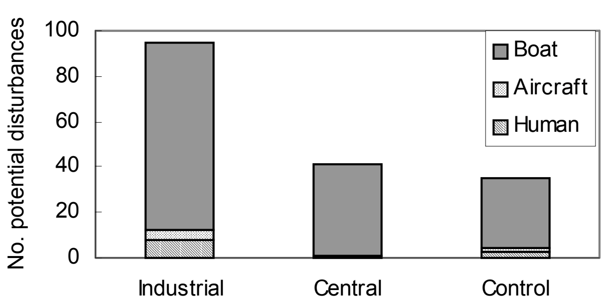

Figure 7. Total number of potential disturbances on transects during Near-shore surveys, 1990-1991, 1999-2000. Potential disturbances included boats (all marine vessels), aircraft (overflights <150 m), and humans (workers on land adjacent to transects).

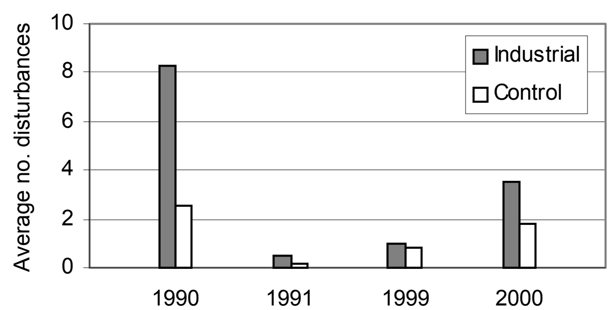

Figure 8. Average number of potential disturbances each year on Industrial and Control transects. Potential disturbances occurred at a higher rate in the Industrial area during each year of the study.

Table 7. Results of ANOVA (A) and ANCOVA (B) tests on Long-tailed Duck log density (Ln[Density+1]), collected on Near-shore surveys in 1990-1991 and 1999-2000.

(A) ANOVA: $R^2 = 0.74$

Term	df	MS	F[1]	P
Disturbance	2	0.868	0.812	0.445
Area	1	154.224	0.702	0.449
Year	3	51.478	7.664	0.004
Area*Year	3	12.076	1.798	0.201
Habitat(Area)	4	219.690	15.749	< 0.001
Year*Habitat(Area)	12	6.717	6.559	< 0.001
Transect(Habitat*Area)	18	13.949	13.053	< 0.001
Year*Transect(Habitat*Area)	54	1.024	0.959	0.561
Residual Error	550	1.069		

(B) ANCOVA: $R^2 = 0.75$, one covariate- Ln(Wave+1)

Term	df	MS	F	P
Disturbance	2	1.107	1.104	0.332
Area	1	142.416	0.679	0.456
Year	3	60.149	8.716	0.002
Area*Year	3	10.748	1.557	0.251
Habitat(Area)	4	209.851	15.212	< 0.001
Year*Habitat(Area)	12	6.901	6.547	< 0.001
Transect(Habitat*Area)	18	13.795	13.753	< 0.001
Year*Transect(Habitat*Area)	54	1.054	1.051	0.381
Ln(Wave+1)	1	37.001	36.893	< 0.001
Residual Error	549	1.003		

[1] See table 2 for error terms used to derive F- statistic

Components of Variation

Five components explained 74% and 75% (ANOVA and ANCOVA, respectively) of the variation in Long-tailed Duck densities (Table 7). First, the significant wave covariate indicated that as wave height increased, density decreased. Second, the significant Year term suggested that Long-tailed Duck densities decreased area-wide from 1990-2000. Scheffe pair-wise comparisons show that 1990 log densities were significantly higher than 1999 ($P = 0.018$) and 2000 ($P = 0.005$; Fig. 6). Third, while Long-tailed Duck densities were the same in the Industrial and Control areas as a whole (ANOVA: $F_{1,4} = 0.702$, $P = 0.449$; ANCOVA: $F_{1,4} = 0.679$, $P = 0.456$), the importance of specific habitats differed between the two areas as shown in a significant Habitat(Area) term. For example, log densities in Mainland Coastline habitat differed significantly ($P = 0.002$) between the Control Area (□ = 3.76 ± 0.27 95% CI) and the Industrial area (□ = 0.91 ± 0.19 95% CI). Fourth, the significant interaction term Year*Habitat(Area), indicated that the Habitats within Areas varied significantly between Years. For example, density of Long-tailed Ducks was relatively high in Barrier Island habitat in the Control area during the summer of 1990 but decreased significantly in subsequent years (Fig. 9). Fifth, while densities of Long-tailed Ducks varied among Area-Habitat strata, the significant term Transect(Habitat*Area) demonstrated that density varied within these strata as well. Thus, Long-tailed Duck density in some transects was consistently high relative to other transects in the same Area-Habitat strata. These fine-scale

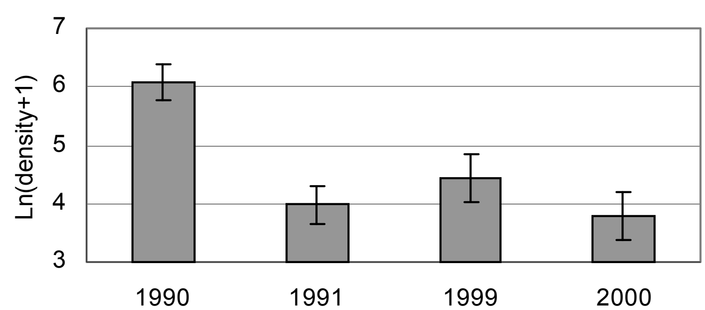

Figure 9. Mean log density (□ 95% CI) of Long-tailed Ducks in Barrier Island habitat within the Control area was variable among years.

differences within given Habitats and Areas were consistent over the four year sampling period, as seen in the non-significant interaction term Year*Transect(Area*Habitat).

Table 8. Potential disturbances recorded on Industrial, Central, and Control transects. Potential disturbances included boats (all marine vessels), aircraft (overflights <150 m), and humans (workers on land adjacent to transects).

		Potential Disturbance			
Area	Transect	Boat	Aircraft	Human	Total
Industrial	22	7	0	0	7
Industrial	23	8	0	1	9
Industrial	24	17	2	0	19
Industrial	25	18	0	3	21
Industrial	30	2	0	0	2
Industrial	31	0	0	1	1
Industrial	32	8	2	0	10
Industrial	33	6	0	1	7
Industrial	202	0	0	2	2
Industrial	301	3	0	0	3
Industrial	401	9	0	0	9
Industrial	402	5	0	0	5
Central	904	5	0	0	5
Central	905	2	0	0	2
Central	907	25	0	0	25
Central	908	2	0	0	2
Central	910	5	0	0	5
Central	911	1	0	0	1
Central	915	0	0	1	1
Control	133	5	0	0	5
Control	135	1	0	1	2
Control	136	1	1	0	2
Control	182	2	0	0	2
Control	183	5	0	0	5
Control	190	2	0	0	2
Control	191	1	0	0	1
Control	192	7	0	2	9
Control	193	7	0	0	7

Near-shore Species Composition and Distribution

In 1999, we increased the range of marine bird sampling beyond transects sampled in 1990-1991 (Fig. 3). Unlike the previous section that reported results of a model designed specifically to identify human related effects on Long-tailed Ducks, here we use data from the expanded sampling area to describe the distribution of a suite of marine birds observed during 12 replicate surveys from 1999-2000.

We recorded 30 avian taxa during Near-shore surveys in 1999-2000 (Tables 9,10; Appendices 1a-k). Among this diverse avifauna, Long-tailed Ducks comprised nearly 80% of all birds counted in the Near-shore study area (Table 10, Fig. 10). Moreover, Long-tailed Ducks were the predominant species in all four habitats sampled: Near-shore Marine- 58%, Barrier Island- 83%, Mid-lagoon- 77%, Mainland Shoreline- 72%. When combined with Long-tailed Ducks, other marine species such as Common Eiders (6%), Shorebirds (*Charadriidae spp.* and

Scolopacidae spp.; 5%), and Glaucous Gulls (*Larus hyperboreus*; 4%) comprised 95% of all species seen in the near-shore environment. The remaining 5% of birds was made up by 26 avian taxa.

In the subsequent sections we report on the distribution patterns of 11 focal species/species groups that together comprised 99% of all observations. These include: Long-tailed Duck, Common Eider, King Eider, Scoter (*Melanitta* spp.), Pacific Loon (*Gavia pacifica*), Red-throated Loon (*Gavia stellata*), Yellow-billed Loon (*Gavia adamsii*), Glaucous Gull, Northern Pintail (*Anas acuta*), Geese and Swans (*Anserinae* spp.), and Shorebirds (*Charadriidae* and *Scolopacidae* spp.). Incidental observations of ten additional taxa seen in the near-shore environment occurred in densities so low that generalizations regarding their distribution patterns are difficult, and thus are not discussed here. These include: Grebe (*Podiceps* spp.), Northern Shoveler (*Anas clypeata*), Scaup (*Aythya spp.*), Red-breasted Merganser (*Mergus serrator*), Jaeger (*Stercorarius spp.*), Sabine's Gull (*Xema sabini*), Arctic Tern (*Sterna paradisaea*), Black Guillemot (*Cepphus grylle*), Gyrfalcon (*Falco rusticolus*), and Common Raven (*Corvus corax*).

Table 9. Counts of all birds observed during 12 Near-shore aerial surveys, Beaufort Sea, Alaska, 1999-2000.

	1999						2000					
Species	22-Jul	30-Jul	11-Aug	26-Aug	2-3-Sep	8-Sep	21-Jul	1-Aug	7-Aug	15-Aug	24-Aug	31-Aug
Yellow-billed Loon	6	10	13	2	0	2	12	9	5	4	3	1
Pacific Loon	60	105	50	55	54	58	39	40	72	17	93	72
Red-throated Loon	11	26	18	9	8	26	1	17	13	6	26	4
Unidentified Loon *spp*.	0	0	0	0	0	5	0	0	0	0	0	0
Grebe *spp*.	0	0	0	0	1	0	0	0	0	0	0	0
Tundra Swan	0	12	0	4	3	2	2	2	8	0	2	18
White-fronted Goose	100	101	55	33	0	4	147	192	213	79	114	107
Snow Goose	1	1	41	0	20	0	80	20	110	67	25	0
Canada Goose	64	0	0	50	15	0	110	235	33	161	15	83
Black Brant	56	5	77	45	26	0	12	20	86	0	0	0
Northern Pintail	10	483	39	29	62	36	346	153	53	95	6	140
Northern Shoveler	0	0	0	0	0	0	0	1	0	0	0	0
Scaup *spp*.	90	1	0	0	0	61	0	0	12	1	5	0
Common Eider	452	667	510	1330	1089	1173	200	272	444	191	178	211
King Eider	41	97	50	2	3	0	1	0	0	0	0	0
Eider *spp*.	29	0	88	0	0	46	5	8	26	71	172	15
Black Scoter	0	0	0	0	0	57	15	2	20	8	0	0
White-winged Scoter	2	0	0	2	0	0	72	0	8	0	10	2
Surf Scoter	148	311	0	52	11	2	30	36	4	63	246	116
Unidentified Scoter *spp*.	0	0	105	113	0	1	0	2	29	25	5	23
Long-tailed Duck	10492	13721	7726	3720	18317	2879	7298	2437	8763	2326	9726	4978
Red-breasted Merganser	5	10	2	44	25	338	0	8	3	0	4	1
Shorebird *spp*.	0	33	694	623	1794	135	86	1071	74	113	54	633
Jaeger *spp*.	0	0	6	6	9	0	0	0	1	0	0	0
Glaucous Gull	311	251	223	375	633	269	642	463	130	359	446	306
Sabine's Gull	0	1	42	0	0	0	2	1	0	12	4	0
Arctic Tern	6	5	8	5	5	15	2	3	1	2	2	1
Black Guillemot	0	0	1	0	0	0	0	0	0	0	0	0
Gyrfalcon	0	0	0	0	0	0	0	0	0	0	0	1
Common Raven	20	0	0	0	0	0	0	0	0	0	0	0
Birds/survey	11904	15840	9748	6499	22075	5109	9102	4992	10108	3600	11136	6712

LONG-TAILED DUCK— Long-tailed Ducks were ubiquitous in the near-shore environment with a total 2,726 flocks sighted in 1999-2000 (median flock size = 10, range 1-999; Table 11). Significant variation in densities occurred both among ($F_{9,32}$ = 20.652, P < 0.001) and within ($F_{32,482}$ = 4.071, P < 0.001) Area-Habitat strata. In general, Long-tailed Duck densities were highest in barrier island habitat throughout the study area, and along the eastern coastline (Figs. 11, 12). In contrast, transects throughout Near-shore Marine, Central Mid-lagoon, and Industrial and Central Mainland Coastline habitats had low densities of Long-tailed Ducks. Among these strata, it is noteworthy that Mainland Coastline transects in the Industrial and Central areas had low densities relative to the Control area.

Table 10. Total count and percent composition of bird species observed during 12 replicate Near-shore surveys, Beaufort Sea, Alaska, 1999-2000.

Species	Total observed	% of total
Yellow-billed Loon	67	0.057
Pacific Loon	715	0.649
Red-throated Loon	165	0.141
Unidentified Loon *Spp*.	5	0.004
Grebe *Spp*.	1	0.001
Tundra Swan	53	0.045
White-fronted Goose	1145	0.980
Snow Goose	365	0.312
Canada Goose	766	0.655
Black Brant	327	0.280
Northern Pintail	1452	1.242
Northern Shoveler	1	0.001
Scaup *Spp*.	170	0.145
Common Eider	6717	5.748
King Eider	194	0.166
Eider *Spp*.	460	0.394
Black Scoter	102	0.087
White-winged Scoter	96	0.082
Surf Scoter	1019	0.872
Unidentified Scoter *Spp*.	303	0.259
Long-tailed Duck	92383	79.049
Red-breasted Merganser	440	0.376
Shorebird *Spp*.	5310	4.544
Jaeger *Spp*.	22	0.019
Glaucous Gull	4408	3.772
Sabine's Gull	62	0.053
Arctic Tern	55	0.047
Black Guillemot	1	0.001
Gyrfalcon	1	0.001
Common Raven	20	0.017
Total	116868	100.00

Table 11. Flock size of birds observed during 12 Near-shore aerial surveys, Beaufort Sea, Alaska, 1999-2000. Species with fewer than 10 flock sightings are not presented.

Species	n	Median	Range	Mean	SE
Yellow-billed Loon	55	1.0	1-3	1.22	0.06
Pacific Loon	514	1.0	1-30	1.39	0.07
Red-throated Loon	109	1.0	1-5	1.51	0.09
Tundra Swan	11	3.0	1-14	4.82	1.36
White-fronted Goose	71	11.0	1-60	16.13	1.78
Snow Goose	12	22.5	1-110	30.42	9.26
Canada Goose	25	18.0	2-125	30.64	6.22
Black Brant	17	10.0	2-60	19.24	4.61
Northern Pintail	102	6.5	1-150	14.24	2.03
Scaup *Spp*.	17	5.0	1-40	10.00	2.90
Common Eider	610	3.0	1-350	11.01	1.20
King Eider	16	6.0	1-90	12.13	5.99
Surf Scoter	97	4.0	1-100	10.51	1.71
Unidentified Scoter *Spp*.	20	4.0	1-100	15.15	5.94
Long-tailed Duck	2726	10.0	1-999	33.89	1.37
Red-breasted Merganser	31	4.0	1-130	14.19	4.94
Shorebird	182	10.0	1-400	29.18	4.02
Jaegar *Spp*.	15	1.0	1-3	1.47	0.17
Glaucous Gull	1509	1.0	1-80	2.92	0.16
Sabine's Gull	11	1.2	1-40	5.64	3.47
Arctic Tern	29	1.0	1-15	1.90	0.48

While Long-tailed Ducks were distributed differently among Area-Habitat strata, densities varied among transects within strata (Table 12) suggesting subtle differences in distribution irrespective of Habitat and Area. For example, densities were significantly greater in transect 31 ($\bar{x}$ = 4.04, ± 0.83 95% CI) than in the adjoining transect 23 ($\bar{x}$ = 2.51, ± 0.68 95% CI) despite similar habitat, and location. These small-scale differences may reflect microhabitat differences such as prey availability, protection from poor weather, or possibly reduced disturbance from human activities.

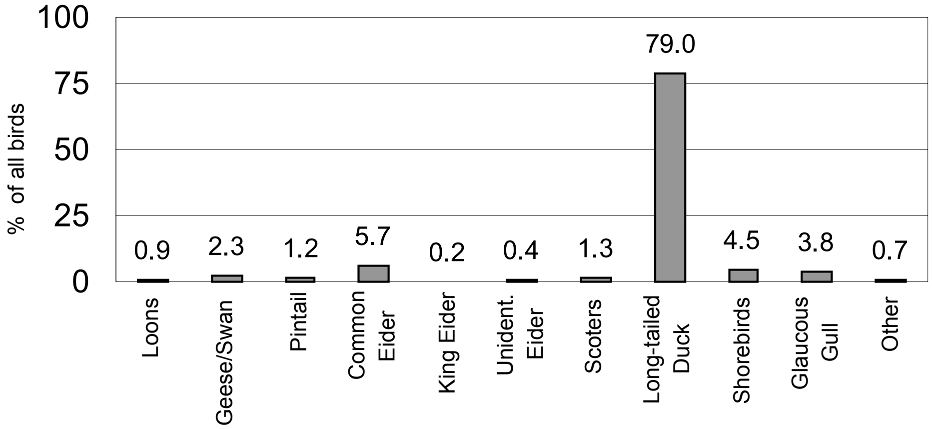

Figure 10. Percent composition of species observed during Near-shore surveys, 1999-2000. Long-tailed Ducks were ubiquitous among all habitats surveyed.

Table 12. Mean log density (Ln[den+1]) of Long-tailed Ducks in transects and habitat-area strata.

Habitat	Area	Transect	Log Density	Strata Mean	Habitat	Area	Transect	Log Density	Strata Mean
Barrier Island					Mainland Coastline				
	Industrial					Industrial			
		201	3.92				25	0.36	
		202	3.17				33	0.45	
		23	2.51				401	1.14	
		31	4.04				402	1.05	
				3.41					**0.75**
	Central					Central			
		907	2.15				913	0.84	
		908	3.30				914	0.25	
		909	3.55				915	1.46	
				3.00					**0.85**
	Control					Control			
		133	4.31				190	2.95	
		134	3.73				191	4.30	
		135	4.18				192	4.06	
		136	4.20				193	2.27	
				4.11					**3.40**
Mid-lagoon					Near-shore Marine				
	Industrial					Industrial			
		24	0.65				101	0.54	
		301	2.17				102	0.21	
		302	1.80				22	0.34	
		32	2.36				30	0.27	
				1.74					**0.34**
	Central					Central			
		910	0.60				904	0.04	
		911	0.13				905	0.76	
		912	0.41				906	0.51	
				0.38					**0.44**
	Control					Control			
		180	2.44				60	0.73	
		181	1.78				61	0.73	
		182	1.82				62	0.84	
		183	0.50				63	0.68	
				1.64					**0.75**

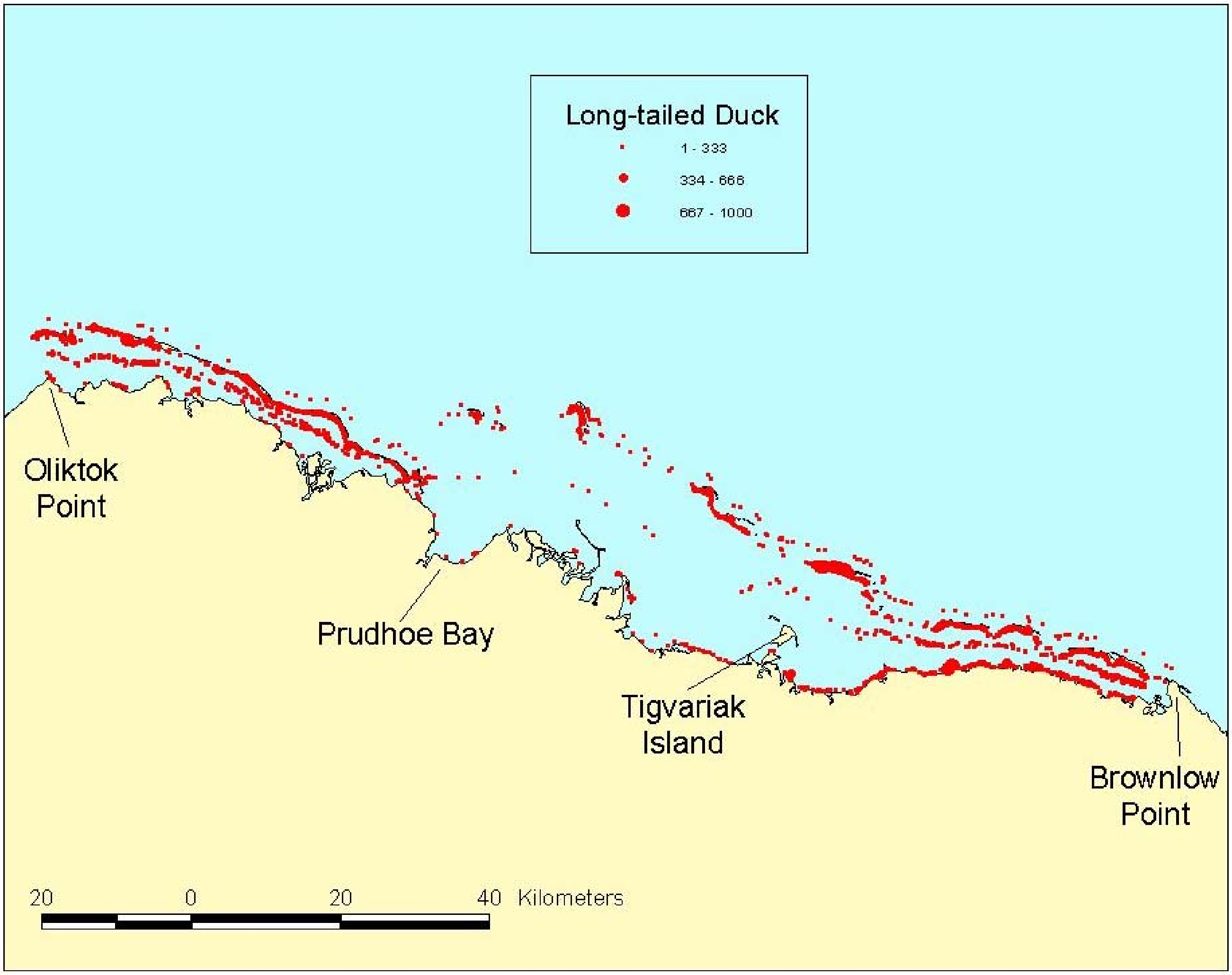

Figure 11. Locations of Long-tailed Ducks during 12 Near-shore surveys, 1999-2000.

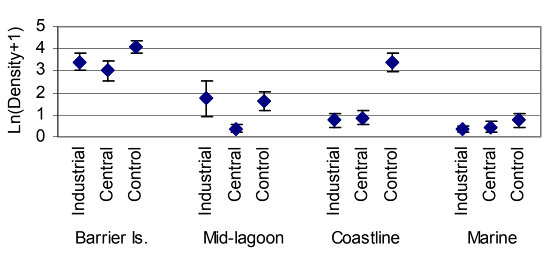

Figure 12. Mean log density (95% CI) of Long-tailed Ducks among four near-shore habitats in Control, Central, and Industrial areas, 1999-2000.

COMMON EIDER—As with Long-tailed Ducks, Common Eider flocks were seen regularly throughout the near-shore environment (median flock size = 3, range 1-350; Table 11). Common Eiders shared a similar distribution with Long-tailed Ducks with densities varying both among ($F_{9,32} = 6.601$, $P < 0.001$) and within ($F_{32,482} = 4.366$, $P < 0.001$) Area-Habitat strata (Figs. 13, 14). Densities of Common Eiders were highest in Barrier Island habitat, particularly in the Central and Control areas. In contrast, Common Eider densities were relatively low in all habitats within the Industrial area.

As with Long-tailed Ducks, distribution of Common Eiders varied within some Area-Habitat strata (Table 13). Notable examples of this were seen in the Control Barrier Islands strata, where densities decreased from west to east. Of these, transect 133 had significantly higher densities than neighboring transects 135 and 136.

Table 13. Mean log density (ln[den+1]) of Common Eiders in transects and habitat-area strata.

Habitat	Area	Transect	Log Density	Strata Mean	Habitat	Area	Transect	Log Density	Strata Mean
Barrier Island					Mainland Coastline				
	Industrial					Industrial			
		201	0.23				25	0.00	
		202	0.47				33	0.00	
		23	0.37				401	0.00	
		31	0.34				402	0.00	
				0.35					**0.00**
	Central					Central			
		907	0.96				913	0.06	
		908	0.89				914	0.30	
		909	1.78				915	0.13	
				1.21					**0.16**
	Control					Control			
		133	2.95				190	0.28	
		134	1.79				191	0.51	
		135	1.41				192	0.37	
		136	0.44				193	0.36	
				1.65					**0.38**
Mid-lagoon					Near-shore Marine				
	Industrial					Industrial			
		24	0.09				101	0.28	
		301	0.00				102	0.00	
		302	0.00				22	0.34	
		32	0.12				30	0.27	
				0.05					**0.22**
	Central					Central			
		910	0.14				904	0.15	
		911	0.01				905	0.01	
		912	0.38				906	0.01	
				0.18					**0.06**
	Control					Control			
		180	0.06				60	0.48	
		181	0.21				61	0.57	
		182	0.54				62	0.17	
		183	0.45				63	0.00	
				0.31					**0.30**

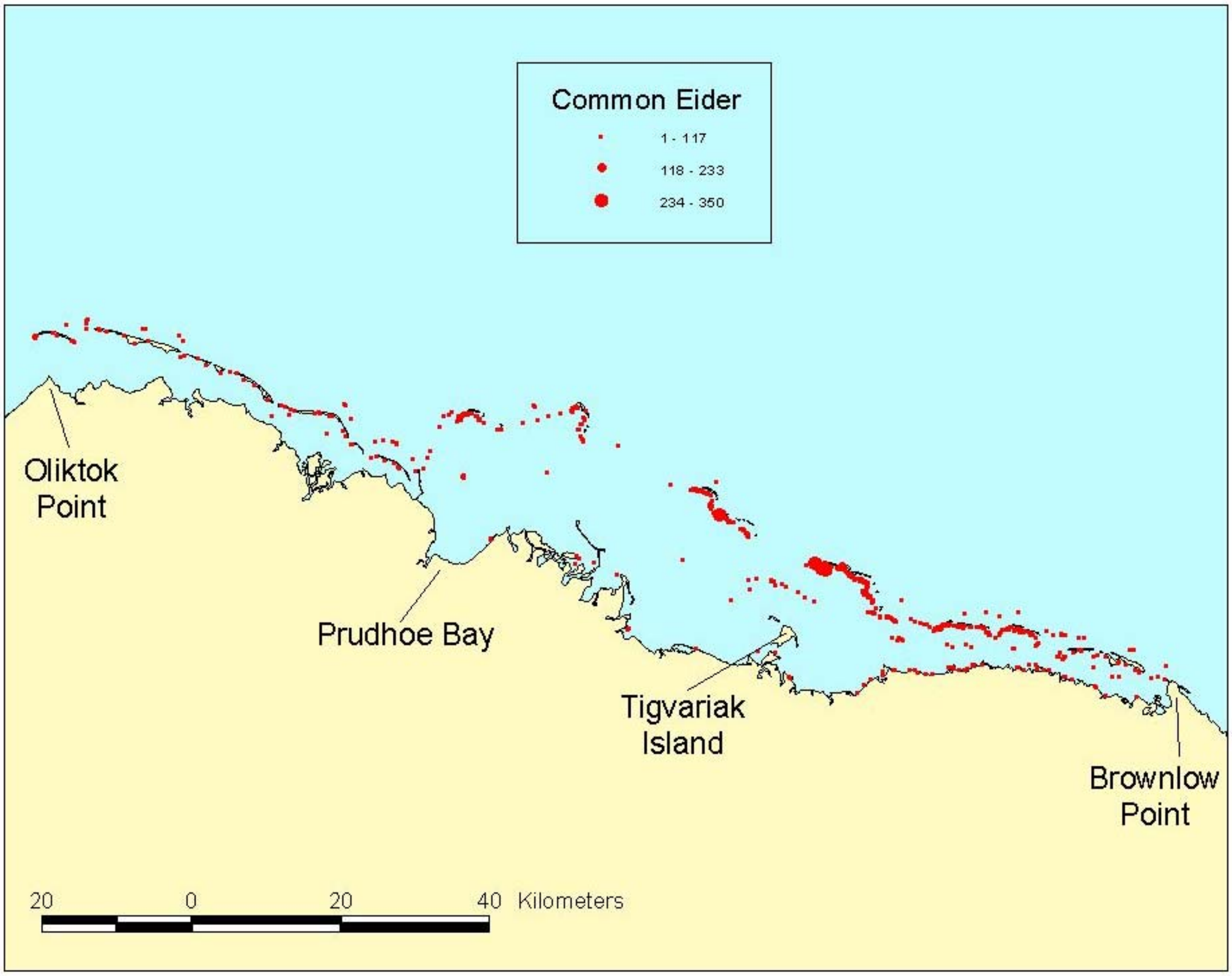

Figure 13. Locations of Common Eiders during 12 Near-shore surveys, 1999-2000.

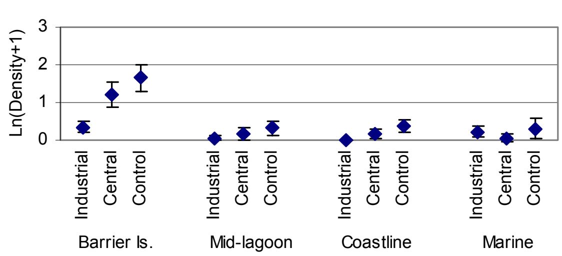

Figure 14. Mean log density (95% CI) of Common Eiders among four near-shore habitats in Control, Central, and Industrial areas, 1999-2000.

KING EIDER—While Common Eiders were seen regularly in the near-shore environment, King Eiders were rarely observed. Those that were observed, however, occurred in relatively large flocks (median flock size = 6, range 1-90; Table 11); and were generally sighted in the Industrial Near-shore Marine stratum (Fig. 15, Table 14). Despite higher mean density in this stratum, no statistical difference was detected among the 12 Area-Habitat strata ($F_{9,32} = 1.196$, $P = 0.331$). Moreover, there was no detectable variability among transects within a stratum ($F_{32,482} = 1.106$, $P = 0.320$). These results are likely due to the high variability of densities between replicates and an overall low sighting rate of this species in the near-shore area.

Table 14. Mean log density (ln[den+1]) of King Eiders in transects and habitat-area strata.

Habitat	Area	Transect	Log Density	Strata Mean
Barrier Island				
	Industrial			
		201	0.00	
		202	0.00	
		23	0.00	
		31	0.00	
				0.00
	Central			
		907	0.09	
		908	0.20	
		909	0.00	
				0.10
	Control			
		133	0.02	
		134	0.00	
		135	0.00	
		136	0.00	
				0.01
Mid-lagoon				
	Industrial			
		24	0.00	
		301	0.00	
		302	0.00	
		32	0.00	
				0.00
	Central			
		910	0.00	
		911	0.00	
		912	0.02	
				0.01
	East			
		180	0.00	
		181	0.05	
		182	0.00	
		183	0.00	
				0.01
Mainland Coastline				
	Industrial			
		25	0.00	
		33	0.00	
		401	0.00	
		402	0.00	
				0.00
	Central			
		913	0.00	
		914	0.00	
		915	0.00	
				0.00
	Control			
		190	0.01	
		191	0.00	
		192	0.00	
		193	0.00	
				0.00
Near-shore Marine				
	Industrial			
		101	0.02	
		102	0.00	
		22	0.00	
		30	0.28	
				0.08
	Central			
		904	0.05	
		905	0.06	
		906	0.00	
				0.04
	East			
		60	0.00	
		61	0.02	
		62	0.00	
		63	0.00	
				0.00

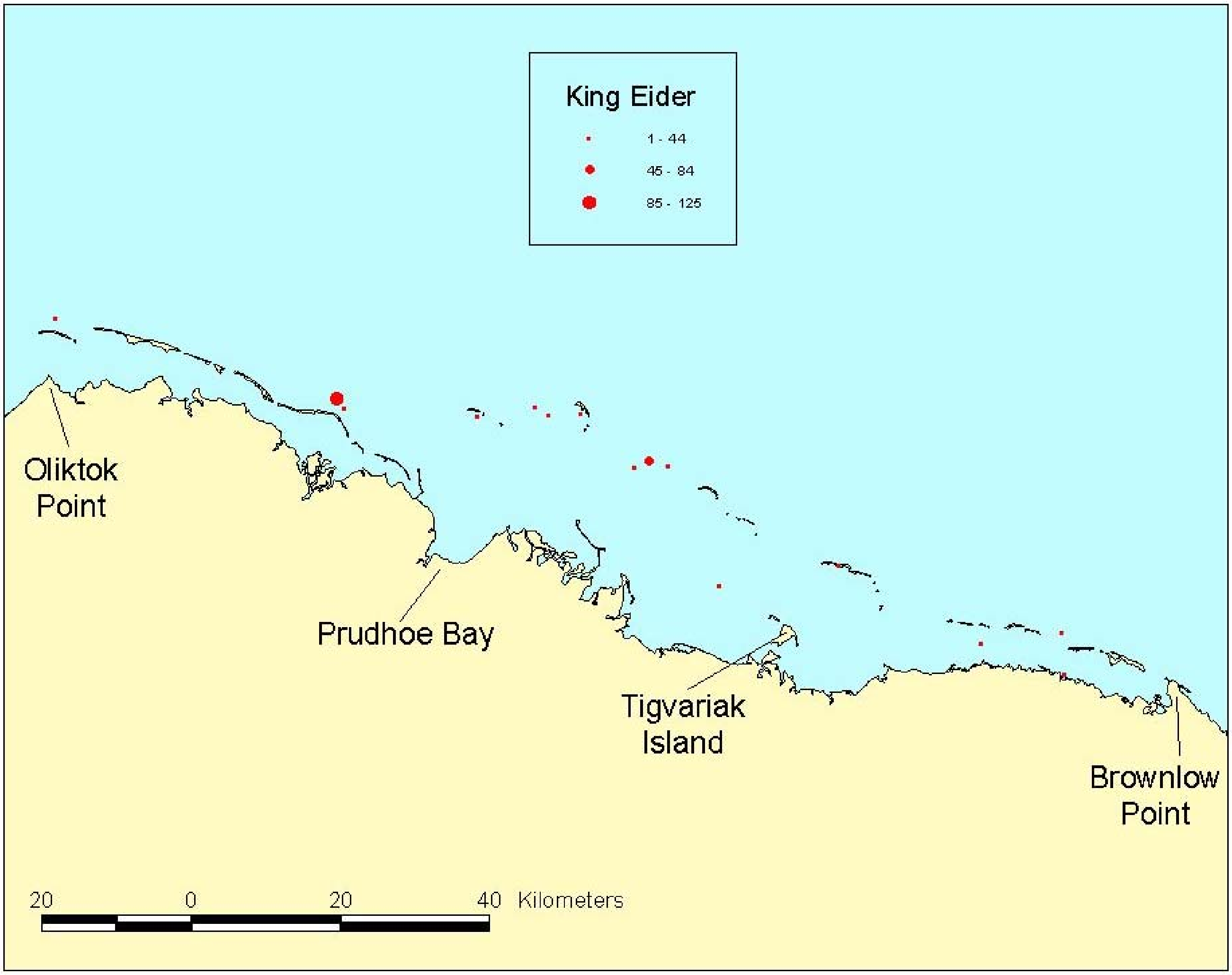

Figure 15. Locations of King Eiders during 12 Near-shore surveys, 1999-2000.

SCOTERS—Surf Scoters (*Melanitta perspicillata*) comprised 84% of all Scoters identified to species, whereas Black Scoter (*M. nigra*) and White-winged Scoter (*M. fusca*) each represented 8% of identified Scoters. Similar to King Eiders, Scoters generally occurred in large flocks (median flock size = 4, range 1-100; Table 11). In contrast to King Eiders, however, Scoters were distributed differently among Area-Habitat strata ($F_{9,32} = 20.652$, $P < 0.001$). While densities were consistently low in most strata, Scoter densities were substantially higher in the Industrial Mid-lagoon (Figs. 16, 17). Scoter density also varied within strata ($F_{32,482} = 1.653$, $P < 0.015$; Table 15). Multiple comparisons, however, did not reveal a significant difference among transects within Area-Habitat strata (P > 0.05), suggesting that insufficient data are available to assess small-scale differences.

Table 15. Mean log density (ln[den+1]) of all Scoters in transects and habitat-area strata.

Habitat	Area	Transect	Log Density	Strata Mean	Habitat	Area	Transect	Log Density	Strata Mean
Barrier Island					Mainland Coastline				
	Industrial					Industrial			
		201	0.24				25	0.00	
		202	0.18				33	0.00	
		23	0.00				401	0.01	
		31	0.29				402	0.00	
				0.18					**0.00**
	Central					Central			
		907	0.20				913	0.02	
		908	0.00				914	0.00	
		909	0.02				915	0.00	
				0.07					**0.01**
	Control					Control			
		133	0.08				190	0.05	
		134	0.00				191	0.05	
		135	0.47				192	0.01	
		136	0.16				193	0.03	
				0.18					**0.03**
Mid-lagoon					Near-shore Marine				
	Industrial					Industrial			
		24	0.23				101	0.03	
		301	1.02				102	0.00	
		302	0.91				22	0.26	
		32	1.08				30	0.00	
				0.81					**0.07**
	Central					Central			
		910	0.04				904	0.02	
		911	0.08				905	0.00	
		912	0.01				906	0.28	
				0.04					**0.10**
	Control					Control			
		180	0.00				60	0.00	
		181	0.07				61	0.00	
		182	0.16				62	0.03	
		183	0.00				63	0.00	
				0.06					**0.01**

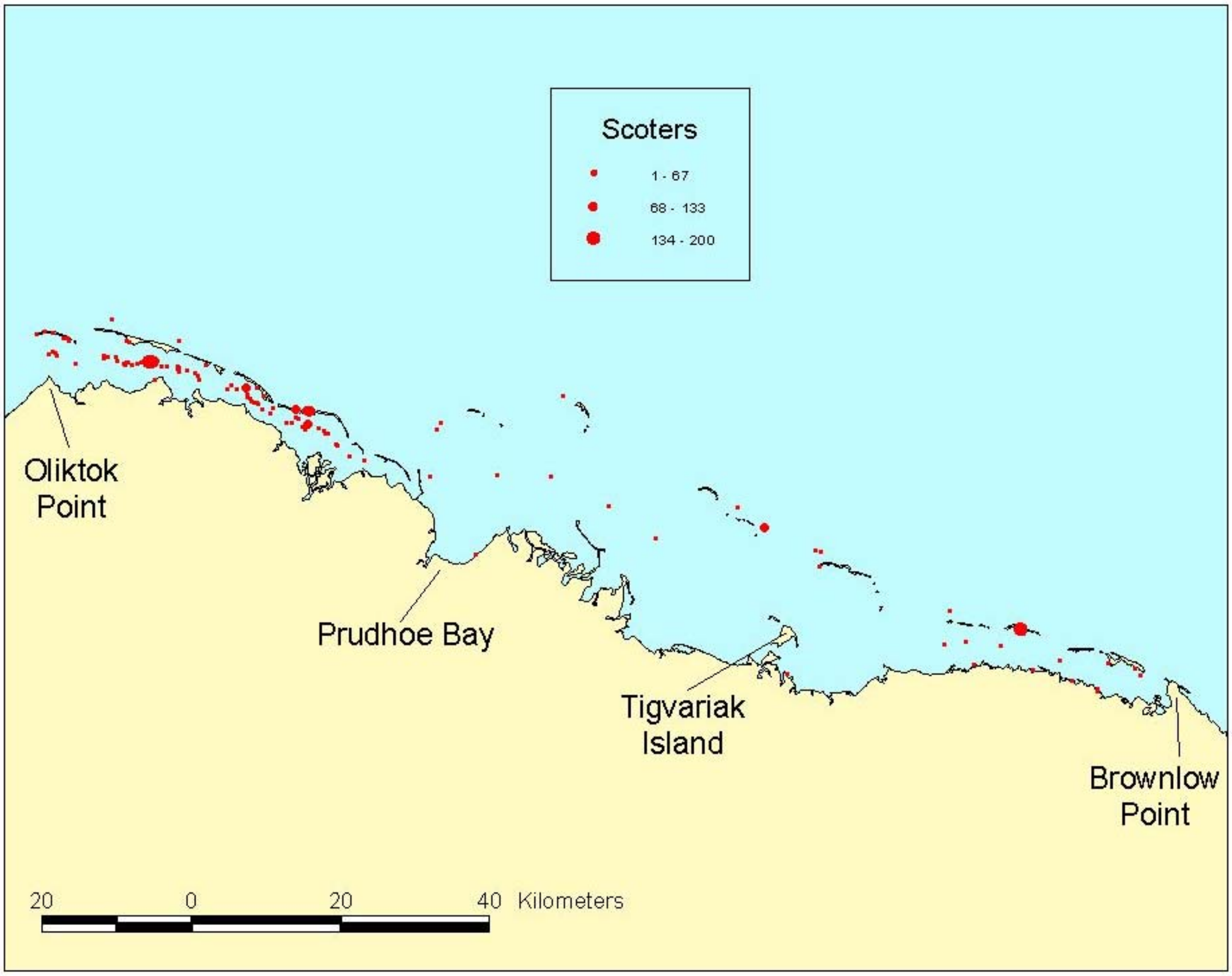

Figure 16. Locations of Scoters during 12 Near-shore surveys, 1999-2000.

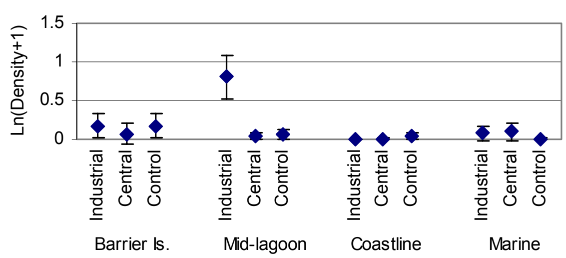

Figure 17. Mean log density (±95% CI) of Scoters among four near-shore habitats in Control, Central, and Industrial areas, 1999-2000.

GLAUCOUS GULL—In contrast to Scoters, Glaucous Gulls occurred as individuals or in small flocks (median flock size = 1, range 1-80; Table 11). The distribution of Glaucous Gulls varied among ($F_{9,32}$ = 19.537, P < 0.001) and within ($F_{32,482}$ = 2.352, P < 0.001) Area-Habitat strata. In general, Glaucous Gull densities were highest along Barrier Island and Mainland Shoreline habitat, while Mid-lagoon appeared less important (Figs. 18, 19). Interestingly, Near-shore Marine habitat was important for this species in the eastern area only.

Within Area-Habitat strata, transect means were significantly different in the western Barrier Islands. Specifically, transect 23 had consistently higher densities than transect 202, a few kilometers to the west (Table 16). This difference contrasts with the distribution of Long-tailed Ducks where densities in transect 23 were significantly lower than neighboring transects in the same stratum.

Table 16. Mean log density (ln[den+1]) of Glaucous-winged Gulls in transects and habitat-area strata.

Habitat	Area	Transect	Log Density	Strata Mean	Habitat	Area	Transect	Log Density	Strata Mean
Barrier Island					Mainland Coastline				
	Industrial					Industrial			
		201	1.36				25	0.49	
		202	0.95				33	0.66	
		23	1.86				401	0.92	
		31	1.22				402	0.44	
				1.35					**0.63**
	Central					Central			
		907	0.77				913	1.07	
		908	1.33				914	1.17	
		909	0.62				915	0.83	
				0.91					**1.03**
	Control					Control			
		133	0.55				190	0.81	
		134	0.69				191	0.66	
		135	0.95				192	0.68	
		136	0.83				193	0.65	
				0.76					**0.70**
Mid-lagoon					Near-shore Marine				
	Industrial					Industrial			
		24	0.12				101	0.40	
		301	0.01				102	0.08	
		302	0.04				22	0.08	
		32	0.05				30	0.07	
				0.06					**0.16**
	Central					Central			
		910	0.14				904	0.14	
		911	0.15				905	0.15	
		912	0.03				906	0.04	
				0.11					**0.11**
	Control					Control			
		180	0.65				60	0.15	
		181	0.14				61	0.05	
		182	0.08				62	0.09	
		183	0.06				63	0.01	
				0.23					**0.08**

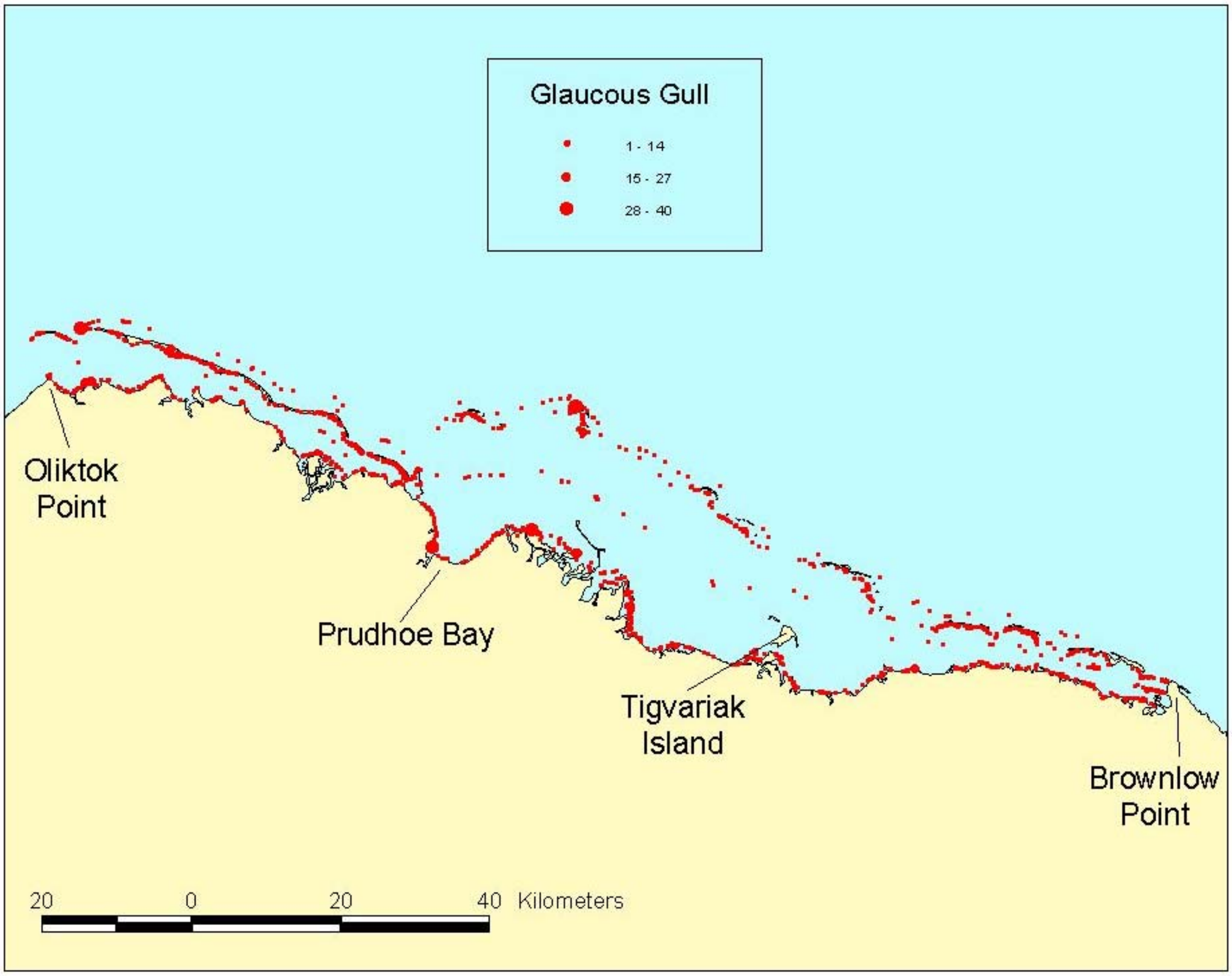

Figure 18. Locations of Glaucous Gulls during 12 Near-shore surveys, 1999-2000.

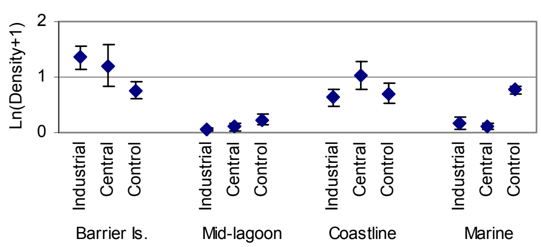

Figure 19. Mean log density (□95% CI) of Glaucous Gulls among four near-shore habitats in Control, Central, and Industrial areas, 1999-2000.

NORTHERN PINTAIL—In contrast to the marine birds previously discussed, Northern Pintails were distributed almost exclusively along the coastline (Fig. 20) in relatively large flocks (median flock size = 6.5, range 1-150; Table 11). Thus, Pintail distribution varied significantly among Area-Habitat strata ($F_{9,32} = 9.132$, $P < 0.001$) with the highest densities occurring throughout the Mainland Coastline strata (Fig. 21). The affinity to coastline was consistent among transects within the Mainland Coastline strata ($F_{32,482} = 1.193$, $P = 0.219$, Table 17). That is, densities did not vary significantly among transects within a given Habitat in an Area.

Table 17. Mean log density (ln[den+1]) of Northern Pintail in transects and habitat-area strata.

Habitat	Area	Transect	Log Density	Strata Mean	Habitat	Area	Transect	Log Density	Strata Mean
Barrier Island					Mainland Coastline				
	Industrial					Industrial			
		201	0.08				25	0.26	
		202	0.00				33	0.24	
		23	0.03				401	0.42	
		31	0.00				402	0.23	
				0.03					**0.29**
	Central					Central			
		907	0.00				913	0.00	
		908	0.01				914	0.80	
		909	0.00				915	0.30	
				0.00					**0.37**
	Control					Control			
		133	0.00				190	0.72	
		134	0.01				191	0.70	
		135	0.02				192	0.23	
		136	0.13				193	0.57	
				0.04					**0.56**
Mid-lagoon					Near-shore Marine				
	Industrial					Industrial			
		24	0.00				101	0.02	
		301	0.00				102	0.01	
		302	0.00				22	0.00	
		32	0.00				30	0.00	
				0.00					**0.01**
	Central					Central			
		910	0.00				904	0.04	
		911	0.00				905	0.01	
		912	0.00				906	0.00	
				0.00					**0.02**
	Control					Control			
		180	0.00				60	0.00	
		181	0.00				61	0.00	
		182	0.00				62	0.00	
		183	0.00				63	0.00	
				0.00					**0.00**

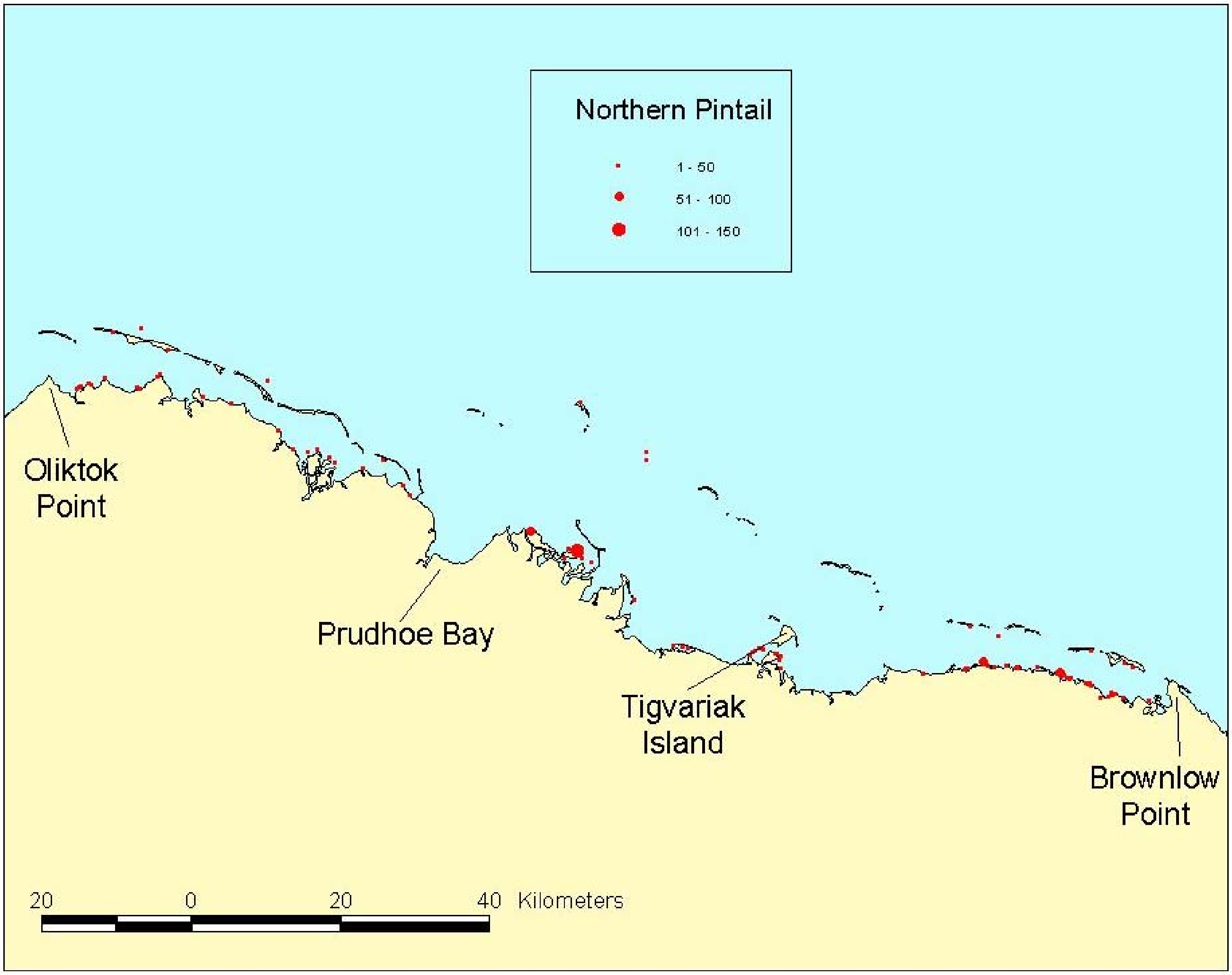

Figure 20. Locations of Northern Pintails during 12 Near-shore surveys, 1999-2000.

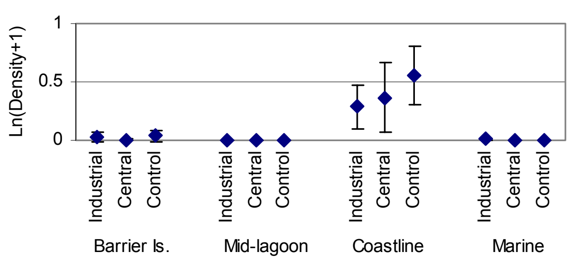

Figure 21. Mean log density (□95% CI) of Northern Pintails among four near-shore habitats in Control, Central, and Industrial areas. 1999-2000.

GEEESE AND SWANS— The Geese and Swan group was composed of White-fronted Geese (*Anser albifrons*), Canada Geese (*Branta canadensis*), Black Brant (*Branta bernicla*), and Tundra Swans (*Cygnus columbianus*). These birds shared a similar distribution with that of Northern Pintail. Specifically, Geese and Swans were concentrated in Mainland Coastline Habitat ($F_{9,32} = 7.382$, $P < 0.001$; Figs. 22, 23). Unlike Pintails, however, their densities tended to be lower in the Control area relative to other Coastline strata, although this difference was not statistically significant. Similarly, Geese and Swan distribution differed from that of Pintails in that densities varied significantly among subtransects within habitat-area strata ($F_{32,482} = 2.786$, $P < 0.001$). For example, within the Central Mainland Coastline stratum, mean log density of Geese and Swans was nearly five times greater in transect 915 than in neighboring 914 (Table 18).

Table 18. Mean log density (ln[den+1]) of Geese and Swan in transects and habitat-area strata.

Habitat	Area	Transect	Log Density	Strata Mean
Barrier Island				
	Industrial			
		201	0.36	
		202	0.14	
		23	0.18	
		31	0.00	
				0.17
	Central			
		907	0.00	
		908	0.00	
		909	0.00	
				0.00
	Control			
		133	0.00	
		134	0.00	
		135	0.18	
		136	0.18	
				0.09
Mid-lagoon				
	Industrial			
		24	0.00	
		301	0.00	
		302	0.00	
		32	0.00	
				0.00
	Central			
		910	0.00	
		911	0.00	
		912	0.00	
				0.00
	Control			
		180	0.00	
		181	0.00	
		182	0.00	
		183	0.00	
				0.00

Habitat	Area	Transect	Log Density	Strata Mean
Mainland Coastline				
	Industrial			
		25	0.27	
		33	0.92	
		401	1.10	
		402	0.96	
				0.81
	Central			
		913	0.50	
		914	0.32	
		915	1.57	
				0.80
	Control			
		190	0.33	
		191	0.34	
		192	0.08	
		193	0.61	
				0.34
Near-shore Marine				
	Industrial			
		101	0.00	
		102	0.00	
		22	0.11	
		30	0.00	
				0.03
	Central			
		904	0.00	
		905	0.00	
		906	0.00	
				0.00
	Control			
		60	0.11	
		61	0.00	
		62	0.00	
		63	0.00	
				0.03

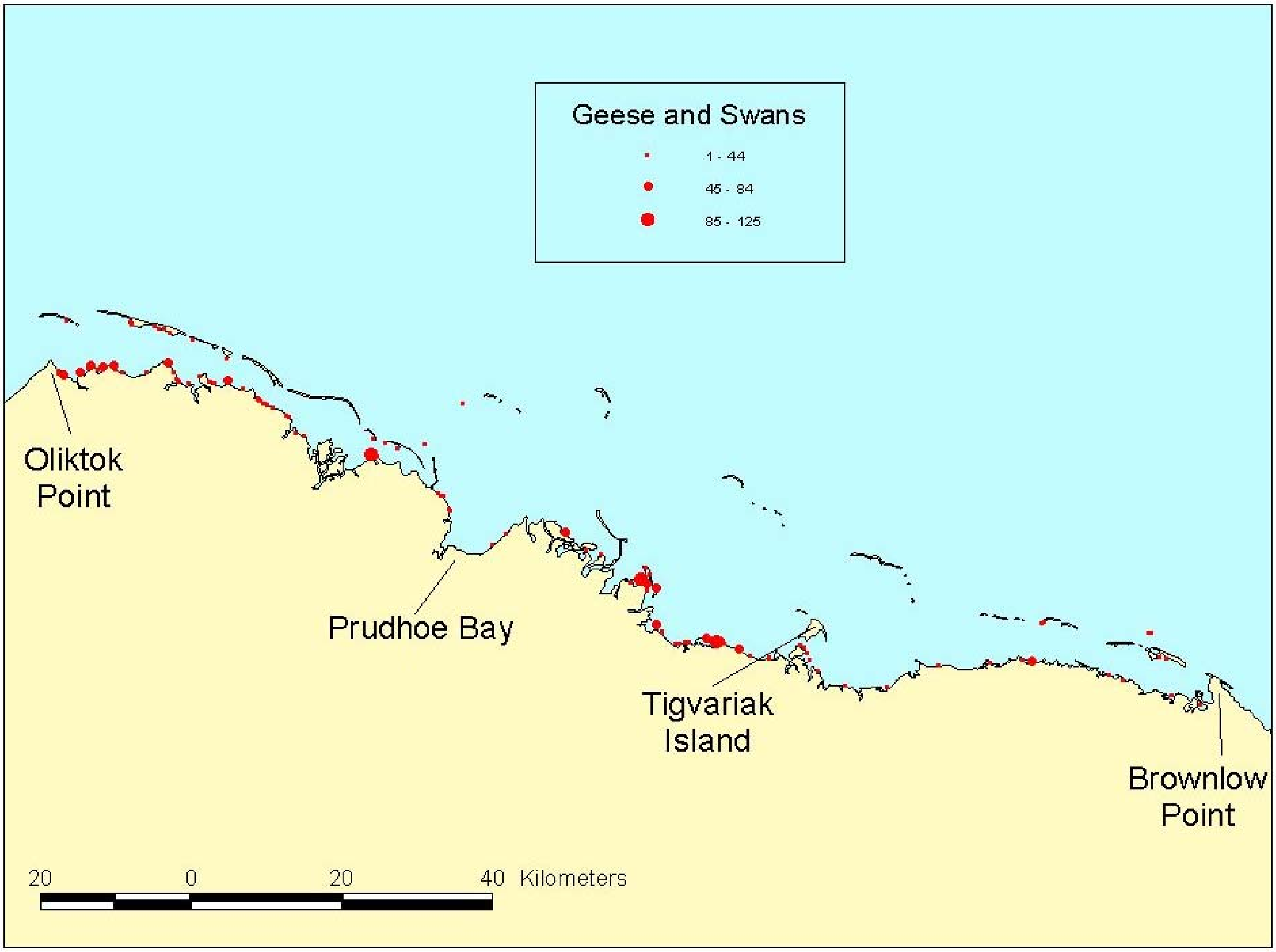

Figure 22. Locations of Geese and Swans during 12 Near-shore surveys, 1999-2000.

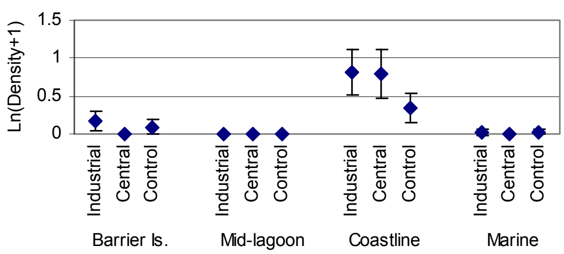

Figure 23. Mean log density (±95% CI) of Geese and Swans among four near-shore habitats in Control, Central, and Industrial areas, 1999-2000.

SHOREBIRDS— Due to their small size, identification of shorebirds to species was difficult. Thus, in this survey we lumped all observations into the broad classification of "Shorebirds" which represented any species belonging to the families *Charadriidae* or *Scolopacidae*. Shorebirds were seen commonly in large flocks (median = 10, range 1-400; Table 11). Densities of this group were highly variable between replicate surveys, particularly in Barrier Island and Mainland Coastline Habitats. Despite fluctuations between counts, densities were significantly higher in the Industrial and Central Barrier Island Strata than elsewhere in the study area ($F_{9,32} = 10.313$, $P < 0.001$; Figs. 24, 25). While significant variation occurred between strata, these differences were consistent within strata ($F_{32,482} = 0.873$, $P = 0.670$; Table 19). Thus, no small-scale differences in densities were detectable.

Table 19. Mean log density (ln[den+1]) of Shorebirds in transects and habitat-area strata.

Habitat	Area	Transect	Log Density	Strata Mean	Habitat	Area	Transect	Log Density	Strata Mean
Barrier Island					Mainland Coastline				
	Industrial					Industrial			
		201	0.66				25	0.15	
		202	0.84				33	0.63	
		23	0.74				401	0.21	
		31	0.77				402	0.04	
				0.75					**0.26**
	Central					Central			
		907	0.36				913	0.33	
		908	0.77				914	0.56	
		909	0.95				915	0.56	
				0.69					**0.48**
	Control					Control			
		133	0.77				190	0.19	
		134	0.12				191	0.16	
		135	0.75				192	0.07	
		136	0.25				193	0.41	
				0.47					**0.21**
Mid-lagoon					Near-shore Marine				
	Industrial					Industrial			
		24	0.00				101	0.07	
		301	0.00				102	0.05	
		302	0.09				22	0.00	
		32	0.00				30	0.00	
				0.02					**0.03**
	Central					Central			
		910	0.00				904	0.03	
		911	0.00				905	0.00	
		912	0.02				906	0.00	
				0.01					**0.01**
	Control					Control			
		180	0.49				60	0.03	
		181	0.00				61	0.00	
		182	0.05				62	0.00	
		183	0.00				63	0.00	
				0.13					**0.01**

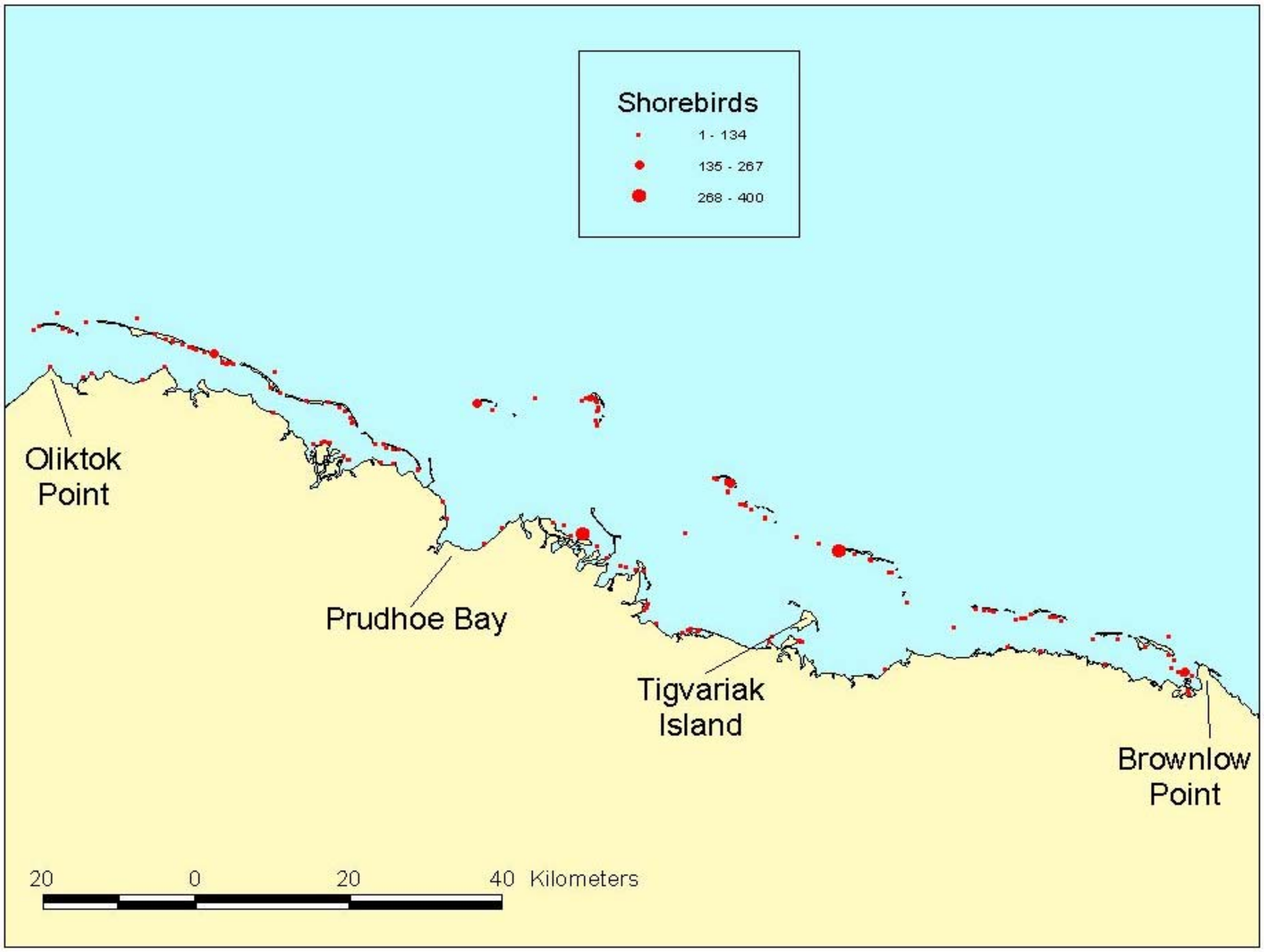

Figure 24. Locations of Shorebirds during 12 Near-shore surveys, 1999-2000.

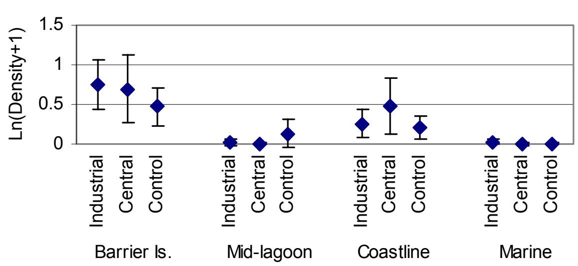

Figure 25. Mean log density (95% CI) of Shorebirds among four near-shore habitats in Control, Central, and Industrial areas, 1999-2000.

PACIFIC LOON—Pacific Loons were the most common loon species observed during Near-shore surveys. They occurred alone, in pairs, and in small flocks (median flock size = 1, range 1-30; Table 11) throughout all habitats (Fig. 26). Given the broad-scale distribution of Pacific Loons, differences in density among Area-Habitat strata were not detectable ($F_{9,32} = 1.891$, $P = 0.090$). Similarly, transects within Area-Habitat strata did not vary significantly ($F_{32,482} = 1.057$, $P = 0.385$; Table 20).

Table 20. Mean log density (ln[den+1]) of Pacific Loons in transects and habitat-area strata.

Habitat	Area	Transect	Log Density	Strata Mean	Habitat	Area	Transect	Log Density	Strata Mean
Barrier Island					Mainland Coastline				
	Industrial					Industrial			
		201	0.20				25	0.23	
		202	0.05				33	0.27	
		23	0.16				401	0.31	
		31	0.35				402	0.30	
				0.19					**0.28**
	Central					Central			
		907	0.09				913	0.14	
		908	0.11				914	0.05	
		909	0.11				915	0.20	
				0.10					**0.13**
	Control					Control			
		133	0.05				190	0.16	
		134	0.12				191	0.30	
		135	0.10				192	0.15	
		136	0.14				193	0.18	
				0.10					**0.20**
Mid-lagoon					Near-shore Marine				
	Industrial					Industrial			
		24	0.18				101	0.14	
		301	0.14				102	0.08	
		302	0.20				22	0.04	
		32	0.26				30	0.09	
				0.20					**0.09**
	Central					Central			
		910	0.20				904	0.08	
		911	0.10				905	0.21	
		912	0.08				906	0.13	
				0.13					**0.14**
	Control					Control			
		180	0.25				60	0.11	
		181	0.09				61	0.16	
		182	0.10				62	0.15	
		183	0.13				63	0.10	
				0.14					**0.13**

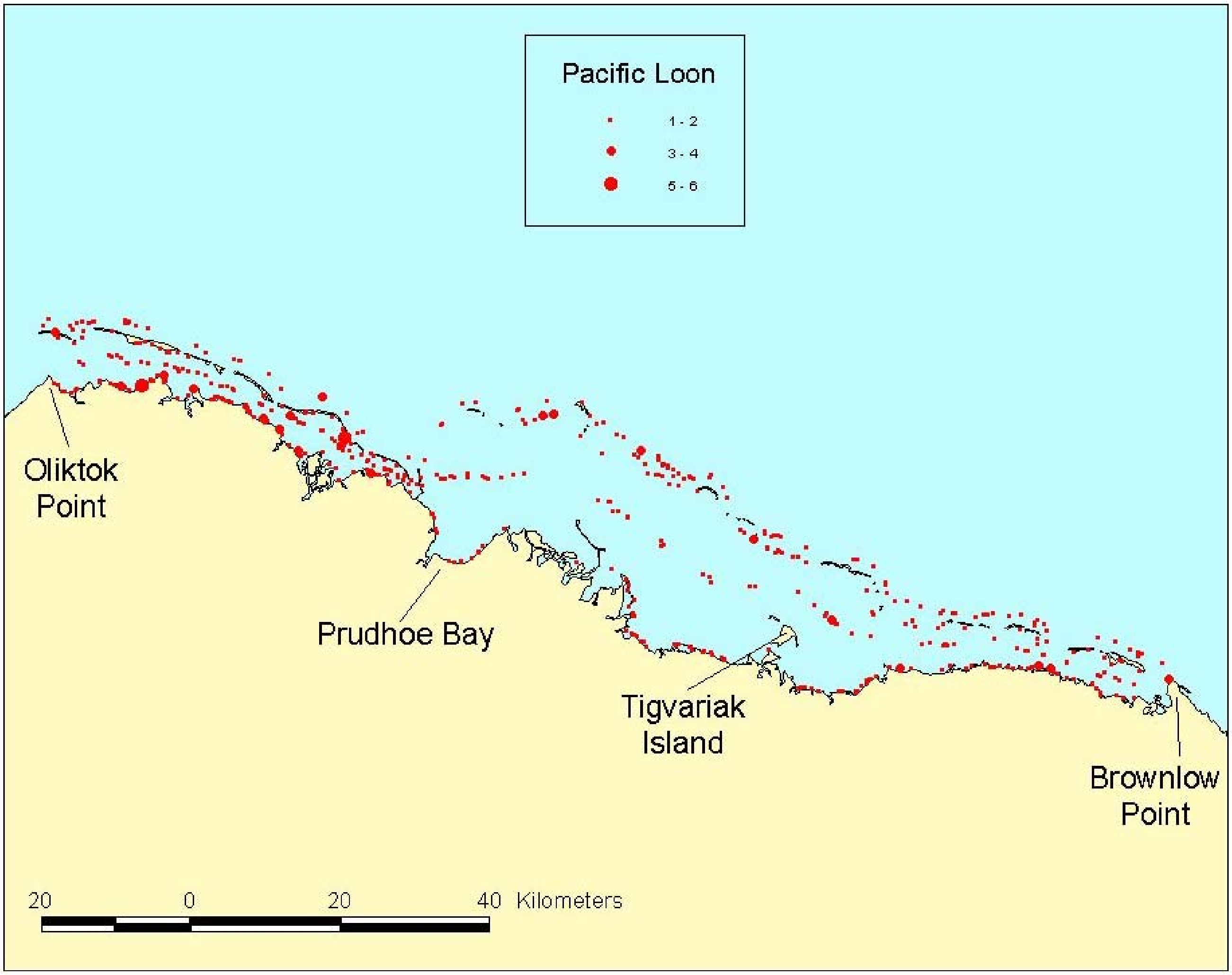

Figure 26. Locations of Pacific Loons during 12 Near-shore surveys, 1999-2000.

RED-THROATED LOON—Unlike Pacific Loons, Red-throated Loons were relatively uncommon in the near-shore environment and occurred in small flocks (median flock size = 1, range 1-5; Table 11). Red-throated Loons tended to occur in Mainland Coastline Habitat with greater frequency than in other habitats, yet this difference was not statistically significant at the alpha = 0.05 level ($F_{9,32} = 2.338$, $P = 0.057$; Fig. 27). Moreover, transects within Area-Habitat strata did not vary ($F_{32,482} = 1.325$, $P = 0.113$; Table 21), suggesting that small-scale differences in densities were not detectable within strata.

Table 21. Mean log density (ln[den+1]) of Red-throated Loons in transects and habitat-area strata.

Habitat	Area	Transect	Log Density	Strata Mean	Habitat	Area	Transect	Log Density	Strata Mean
Barrier Island					Mainland Coastline				
	Industrial					Industrial			
		201	0.05				25	0.05	
		202	0.00				33	0.05	
		23	0.03				401	0.09	
		31	0.04				402	0.10	
				0.03					**0.07**
	Central					Central			
		907	0.00				913	0.08	
		908	0.01				914	0.01	
		909	0.02				915	0.11	
				0.01					**0.07**
	Control					Control			
		133	0.06				190	0.13	
		134	0.01				191	0.13	
		135	0.01				192	0.06	
		136	0.10				193	0.02	
				0.05					**0.09**
Mid-lagoon					Near-shore Marine				
	Industrial					Industrial			
		24	0.02				101	0.00	
		301	0.04				102	0.01	
		302	0.00				22	0.07	
		32	0.01				30	0.05	
				0.02					**0.03**
	Central					Central			
		910	0.10				904	0.00	
		911	0.00				905	0.02	
		912	0.01				906	0.02	
				0.04					**0.01**
	Control					Control			
		180	0.06				60	0.04	
		181	0.00				61	0.00	
		182	0.00				62	0.03	
		183	0.00				63	0.00	
				0.02					**0.02**

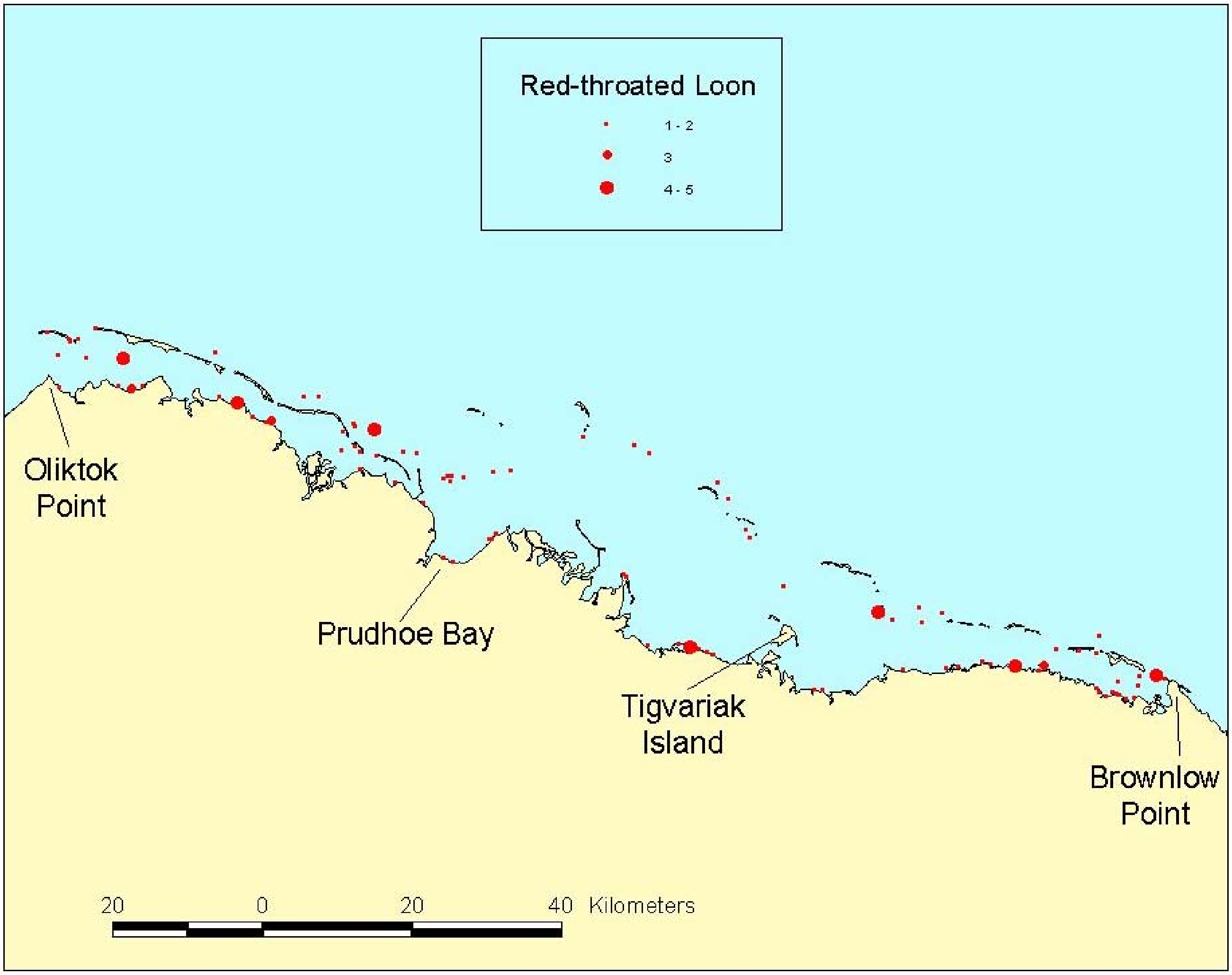

Figure 27. Locations of Red-throated Loons during 12 Near-shore surveys, 1999-2000.

YELLOW-BILLED LOON—As with Red-throated Loons, Yellow-billed Loons were uncommon in the near-shore environment. Mean flock size was the lowest of all marine birds recorded during the surveys (median flock size = 1, range 1-3; Table 11) and overall counts were lower than other taxa groups whose distribution is described in this report (Table 10). Regardless, densities of Yellow-billed Loons were significantly different among given Area-Habitat strata ($F_{9,32} = 3.175$, $P = 0.007$; Figs. 28, 29). Specifically, densities were highest in Industrial and Control Barrier Islands and lowest in the Near-shore Marine Habitat. Despite considerable variation between Area-Habitat strata, transects within Area-Habitat strata were not significantly different ($F_{32,482} = 1.249$, $P = 0.168$; Table 22). While this result suggests that small-scale differences in densities did not occur within strata, the low abundance of this species overall makes detecting significant differences difficult.

Table 22. Mean log density (ln[den+1]) of Yellow-billed Loons in transects and habitat-area strata.

Habitat	Area	Transect	Log Density	Strata Mean	Habitat	Area	Transect	Log Density	Strata Mean
Barrier Island					Mainland Coastline				
	Industrial					Industrial			
		201	0.07				25	0.00	
		202	0.04				33	0.00	
		23	0.02				401	0.00	
		31	0.09				402	0.06	
				0.05					**0.01**
	Central					Central			
		907	0.02				913	0.01	
		908	0.00				914	0.00	
		909	0.03				915	0.02	
				0.01					**0.01**
	Control					Control			
		133	0.06				190	0.00	
		134	0.03				191	0.00	
		135	0.01				192	0.00	
		136	0.10				193	0.00	
				0.05					**0.00**
Mid-lagoon					Near-shore Marine				
	Industrial					Industrial			
		24	0.05				101	0.01	
		301	0.00				102	0.00	
		302	0.04				22	0.00	
		32	0.01				30	0.00	
				0.03					**0.00**
	Central					Central			
		910	0.01				904	0.00	
		911	0.01				905	0.00	
		912	0.00				906	0.00	
				0.01					**0.00**
	Control					Control			
		180	0.01				60	0.00	
		181	0.00				61	0.00	
		182	0.03				62	0.00	
		183	0.00				63	0.02	
				0.01					**0.01**

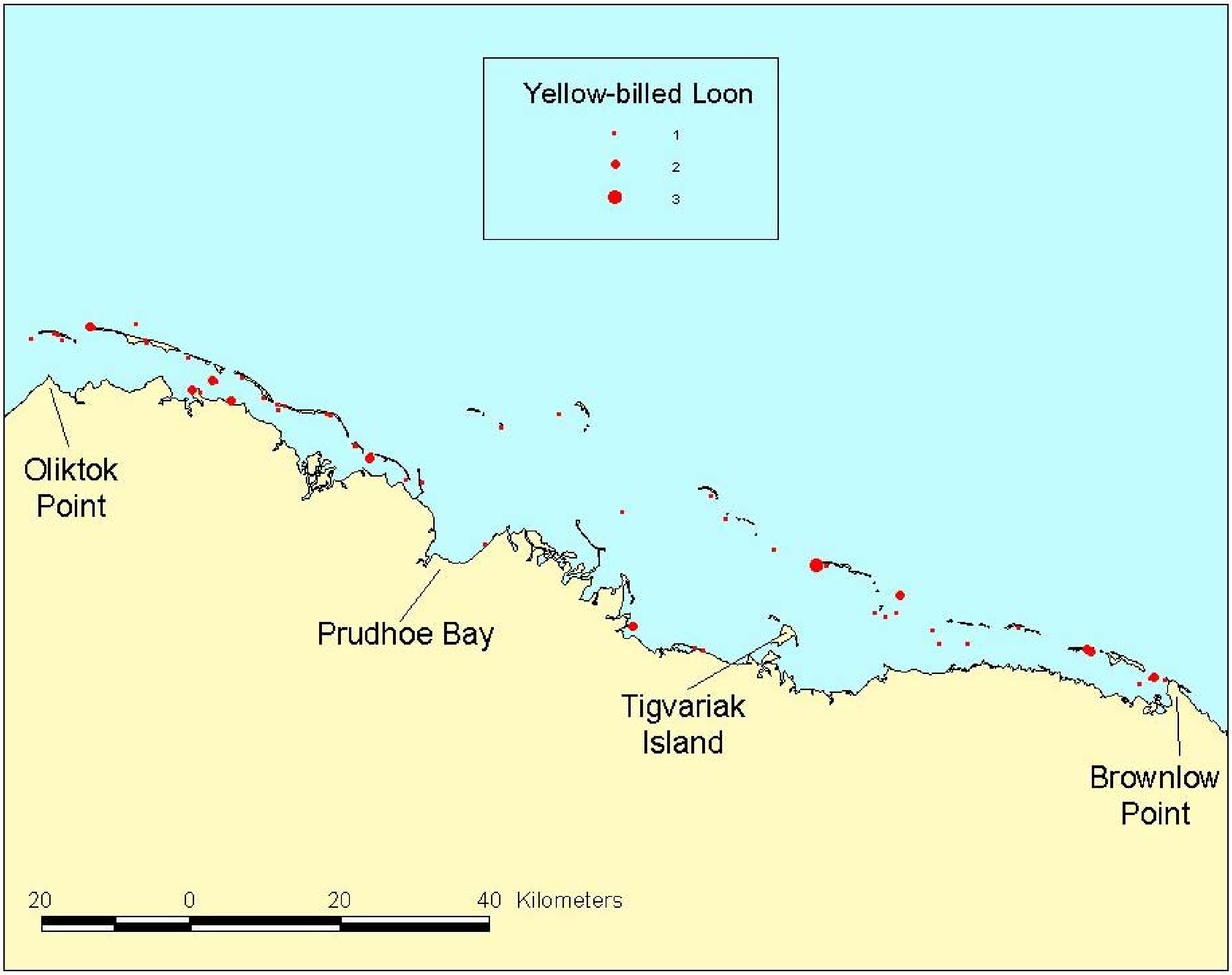

Figure 28. Locations of Yellow-billed Loons during 12 Near-shore surveys, 1999-2000.

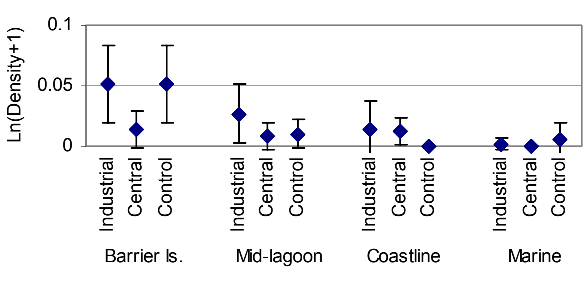

Figure 29. Mean log density (95% CI) of Yellow-billed Loons among four near-shore habitats in Control, Central, and Industrial areas, 1999-2000.

Bias Due to Changes in Survey Platform

Due to concerns that aircraft type may influence density estimates of marine birds, we tested the effect of survey platform (single-engine, twin-engine) on the log density of Long-tailed Ducks. We chose to examine Long-tailed Ducks because they were the focal species of inter-area trend comparisons, and they occurred in higher numbers (Table 10) and larger flocks (Table 11) than other species observed in this study. This approach reduced the possibility of committing a Type II error (Johnson and Gazey 1992).

Two statistical tests were completed to measure potential bias due to survey platform. The results of these tests were equivocal. A two-tailed *t*-test comparing log density estimates from the single-engine surveys vs. twin-engine surveys revealed no significant difference between the groups (single-engine $\bar{x}$ = 3.00 ± 0.08 SE, twin-engine $\bar{x}$ = 3.02 ± 0.28 SE; *t*-test: t_{646} = -0.059, $P = 0.953$). When the factor Platform was included in the ANCOVA model, however, Platform was statistically significant (Table 23). That is, when all factors and covariates were controlled for, the least squares means were significantly different between the groups (single-engine $\bar{x}$ = 3.12 ± 0.14 SE, twin-engine $\bar{x}$ = 3.59 ± 0.22 SE; $F_{1,549} = 11.954$, $P = 0.008$.

Table 23. Results of ANCOVA on Long-tailed Duck log density (Ln[Density+1]) while controlling for Platform.

$R^2 = 0.76$

Term	df	MS	F[1]	P
Disturbance	2	1.105	1.114	0.329
Area	1	143.212	0.681	0.456
Year	3	62.454	9.072	0.002
Area*Year	3	10.844	1.575	0.247
Habitat(Area)	4	210.332	15.216	< 0.001
Year*Habitat(Area)	12	6.884	6.531	< 0.001
Transect(Habitat*Area)	18	13.823	13.931	< 0.001
Year*Transect(Habitat*Area)	54	1.054	1.062	0.361
Ln(Wave+1)	1	31.443	31.689	< 0.001
Platform	1	6.959	7.013	0.008
Residual Error	548	0.992		

[1] See table 2 for error terms used to derive F- statistic

The Near-shore Survey was not designed to test the effect of survey platform on sightability of marine birds. The attempt to ascertain the importance of Platform, therefore, is difficult given the restriction of a twin-engine aircraft to 1999 only. Nonetheless, the possibility that Platform may have influenced our results prompted us to treat this factor as a nuisance parameter, control for it in the ANCOVA model and reassess the hypotheses that were designed to test for industry effects. When we did this, the results of our inter-area trend comparisons and correlation between human activity and bird distribution remained unchanged (Tables 7, 23) indicating that type of aircraft used was unimportant when evaluating the effects of human activities on Long-tailed Ducks.