Marine Mammal and Seabird Surveys

Tidal Energy Demonstration Site — Minas Passage, 2009

Submitted to:

Fundy Ocean Research Centre for Energy (FORCE)

Submitted by:

Envirosphere Consultants Limited
Windsor, Nova Scotia

March 10, 2010

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EXECUTIVE SUMMARY

The Province of Nova Scotia and the Fundy Ocean Research Centre for Energy (FORCE) are presently developing a tidal energy demonstration facility to provide test facilities for tidal energy technologies in the Minas Passage area of Nova Scotia's Bay of Fundy. Water-associated birds (seabirds, waterfowl and shorebirds) and marine mammals (seals, dolphins and porpoises, and whales) are important components of the marine ecosystem in Minas Passage that could potentially interact with tidal devices. One-day surveys for marine mammals and seabirds were carried out between Parrsboro and Cape Spencer in June, July, August and September 2009, to provide baseline information to assess potential for impacts and for development of an environmental monitoring program for the demonstration facility. Twelve bird species including: seabirds (Herring Gull, Black-Backed Gull, Ring-Billed Gull, Black Guillemot, Northern Gannet, and Greater Shearwater), waterfowl (Common Eider, Double-Crested Cormorant, Common Loon, Pacific Loon, White-winged Scoter), and shorebirds (Red Phalarope) were observed. Abundances were generally lower than in the Outer Bay of Fundy and other coastal areas in Atlantic Canada. Marine mammals, all which occurred occasionally, were observed throughout the study area, including Harbour Porpoise (most commonly observed), White-sided Dolphin, Harbour Seal, and, unidentified whales. Herring Gull was the most abundant and common seabird. Common Eider, a coastal seaduck species, was next in abundance, occurring occasionally in large flocks. Great Black-backed Gull ranked third in abundance overall and in frequency of occurrence. The remaining species were present generally in low numbers and occurred infrequently. Overall abundance of birds peaked in July-August but individual species often showed occurrences in particular months. Seasonal patterns in abundance, reflecting the peak in summer (July-August) abundance and activity of birds, predominated, and differences between the study sub-areas (Minas Basin, Minas Passage and Minas Channel) were less important. Marine mammals occurred only in June-August, with a peak in the July-August period.

1. INTRODUCTION

In 2007, the Province of Nova Scotia initiated a process aimed at developing tidal energy resources of the Bay of Fundy, as part of its strategy to meet Provincial renewable energy goals. The process resulted in the completion of a Strategic Environmental Assessment (SEA) in early 2008, which assessed the Bay of Fundy environment and potential impacts of various tidal energy technologies, and subsequently resulted in the award of initial funding to support the creation of a tidal energy demonstration facility in the Nova Scotia portion of the Bay of Fundy near Cape Split. Minas Basin Pulp and Power Company Limited, the successful contractor in the process carried out necessary background studies—geophysical surveys and seabed photographic surveys were done and assessed; public consultation, reviews of shipping traffic and local lobster fisheries and a preliminary seabird and marine mammal survey were carried out—and finally a suitable demonstration site in northern Minas Passage slightly west of Cape Sharp was selected (Figure 1). Subsequently, three berths (circular areas of the seabed 200 m in diameter) and associated cable routes to shore were selected for use by tidal device providers/consortia initially expressing interest, including the teams of Minas Basin Pulp and Power/Marine Current Turbines; Nova Scotia Power Inc (NSPI)/OpenHydro; and Clean Current/Alstom. The oversight body for the facility, the Fundy Ocean Research Centre for Energy (FORCE) was duly established in late 2009.

Seabirds and marine mammals are important components of the marine ecosystem, and in the context of tidal power development, they have the potential to interact with tidal turbines and associated activities. The location of the tidal energy demonstration site is known to support various seabird, waterfowl and marine mammals species common to coastal environments; however detailed information that can be used in monitoring and impact assessment is not available for the site. Consequently the project carried out preliminary surveys in July and October 2008 as part of geophysical cruises to the area to obtain information on occurrence and species composition at the site (Envirosphere Consultants Limited 2009). A comprehensive survey program was established in 2009, with single day-long seabird surveys conducted in June, July, August and September 2009 to provide additional baseline information for the assessment of potential impacts and for the development of an environmental monitoring program for the project, a condition for the Environmental approval for the project obtained in September 2009.

2. METHODS

One-day surveys for marine mammals and seabirds were carried out from chartered lobster boats (Croyden Wood Jr., Parrsboro, June and August 2009; and Ed and Fred Huntley, Scots Bay, July & September 2009), departing from those respective locations at high tide on June 17, July 17, August 16, and September 13, 2009[1]. Surveys were carried out by Mr. Fulton Lavender, an experienced observer for seabirds and marine mammals. All surveys were done under good observation conditions and covered areas in Minas Basin, Minas Passage, and Minas Channel between Parrsboro and Cape Spencer. The standard watch for seabirds was carried out modeled after the Canadian Wildlife Service protocol (Wilhelm *et al.* 2008) but omitting 'snapshot' sampling for flying birds[2], although all flying birds seen in the 5-minute period were counted. Watches of 5-minute duration were carried out as often as possible during the survey while the vessel was in motion, every 10 to 15 minutes for the June and September surveys, and mostly every five minutes for the July and August surveys. One of the five-minute observation periods every 30 minutes was always done on the port side of the boat as a standard, although

[1] Survey times were chosen to catch a high tide early in the morning to allow a full tidal cycle during daylight hours.

[2] The 'snapshot' is an instantaneous count of flying birds within a 300 m radius of the observer and was omitted. All flying birds were included in the normal sampling routine, however, although the density estimate obtained is likely to be higher than if the 'snapshot' approach was used.

this distinction was not needed for subsequent analysis. The observer monitored a strip of water and air 300 m wide approached by the vessel, alternating for each 5-minute period between port and starboard sides, recording information on counts, identification, stage (adult, immature, juvenile etc.), distance (distance classes as required in Wilhelm et al. (2008)), as well as on birds observed beyond 300 m. At the beginning of each observation period, the observer recorded the time, vessel coordinates, heading, speed, windspeed, and weather conditions. All data was recorded in notebooks and subsequently transferred to the CWS standard form for a moving vessel survey (Wilhelm et al. 2008). At the same time, the observer carried out continuous watches with binoculars for marine mammals, and any sightings by the vessel crew were investigated. A protocol and reporting forms used by DND-MARLANT for marine mammal observations, including the MARLANT Whale identification Guide (Envirosphere Consultants 2006) were on board for use in identification. After this data is used in this project, the data will be given to the Canadian Wildlife Service and to Fisheries and Oceans Canada for inclusion in respective seabird and marine mammal databases.

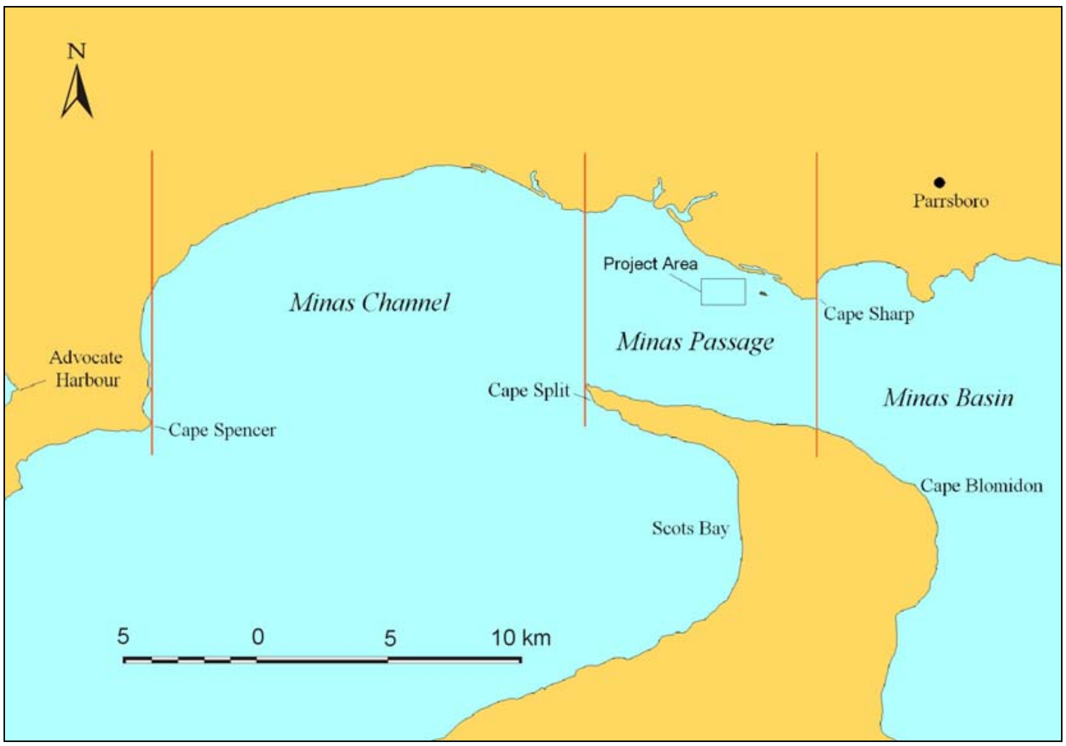

Figure 1. Study area showing project location and major subdivisions.

The survey route (Figures 2a & b) was designed to provide coverage of not only the study site but also of areas to the east (Minas Basin) and west (Minas Channel) since these areas are likely to have seabird distributions which will overlap the tidal demonstration site; to cover nearshore areas as well as along the axis of Minas Passage-Minas Channel; and also to cover daily movements of birds within the general area (e.g. for feeding)[3]. A survey lasted typically from early morning to evening, from one high tide to the next, allowing transects at the project site to be done before the peak ebb and repeated after the peak flood, thereby reducing the amount of time steaming against the tide. After sampling at the project site, the boat steamed with the peak tidal flow to Cape Spencer, where it waited until the tide reversed, and then cruised back again to the survey origin. For the purposes of data analysis, the study area was divided into three sub-areas: Minas Passage was between Cape Sharp and Cape Split; Minas Basin was east of Cape Sharp; and Minas Channel the area west of Cape Split (Figure 1).

[3] . The survey design was reviewed by D. Fifield, CWS, St. John’s, NL, prior to implementation.

For each observation period, the distance traveled based on beginning and end coordinates of the period, as well as based on heading and ship speed, was calculated. Although the two were moderately correlated, the distance based on coordinates proved to be less consistent, containing occasional unreasonably high values assumed to be due to position-recording errors; consequently the distance estimate based on heading and time was used. Seabird densities are estimated and presented in several different ways in this report: as total numbers of birds or numbers of individual species observed in 5-minute observation periods (maps); as an areal density estimate based on numbers seen 'in transect' (i.e. in the 300 m band on the side of the track traversed by the ship, and therefore the most quantitative estimate); as well as total or individual species abundances per kilometer (includes all birds seen within and outside of the 300 m quantitative observation band and which typically includes more species than the area estimate). Abundance expressed per unit area is a more accurate estimate of density of offshore birds' although it may exclude some species. Because 'snapshots' were not done (the 'snapshot' is a procedure to observe flying birds at one point in time and therefore avoid the possibility that they would fly back into the area during the observation period and be recounted), the density of flying birds may be overestimated in this survey (e.g. Wilhelm et al. 2008).

Differences in abundance between area and month were tested for statistical significance by a non-parametric statistical test (Kruskal Wallace One-Way Analysis of Variance) (Sokal and Rohlf 1981) since abundance data was characterized by non-normal (highly skewed) frequency distributions, typically with a high proportion of zero occurrences (no birds observed in the observation period)(see Appendix A for frequency distributions of total bird abundance and for dominant species). A two-way ANOVA with interactions was applied to the log (x+1) transformed dataset to determine significances of differences between areas and months. The SYSTAT Version 5.0 statistical package, (SYSTAT Inc, Evanston, Illinois) was used for all analyses.

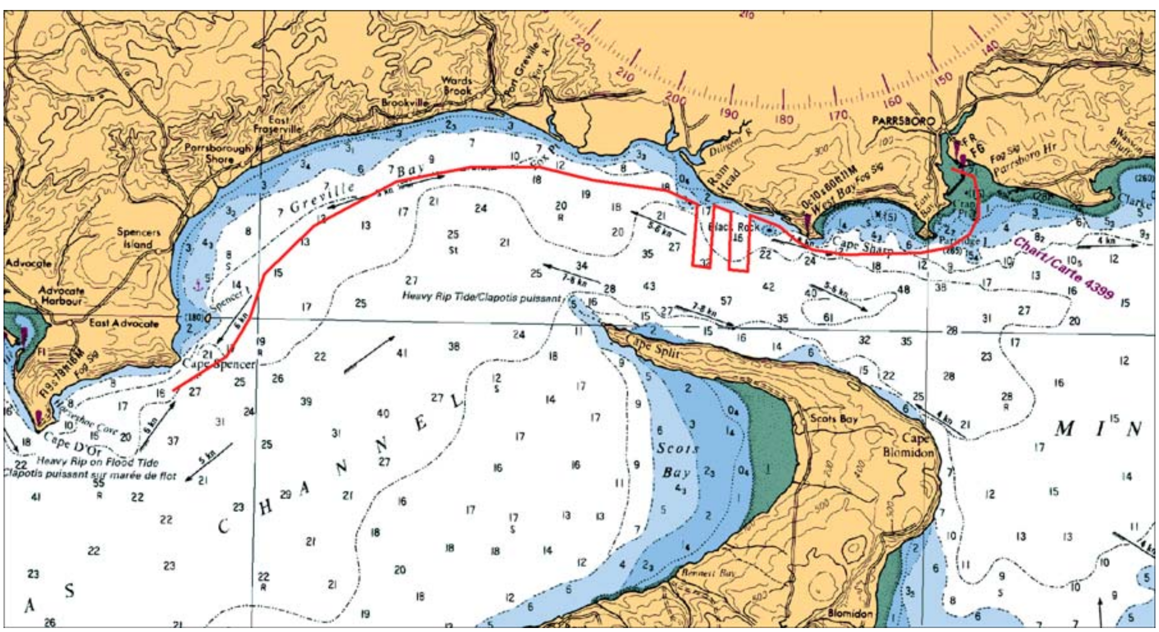

Figure 2a. Location of outgoing survey route, shown leaving Parrsboro. Surveys based in Scots Bay (July and September) joined the survey route off Parrsboro.

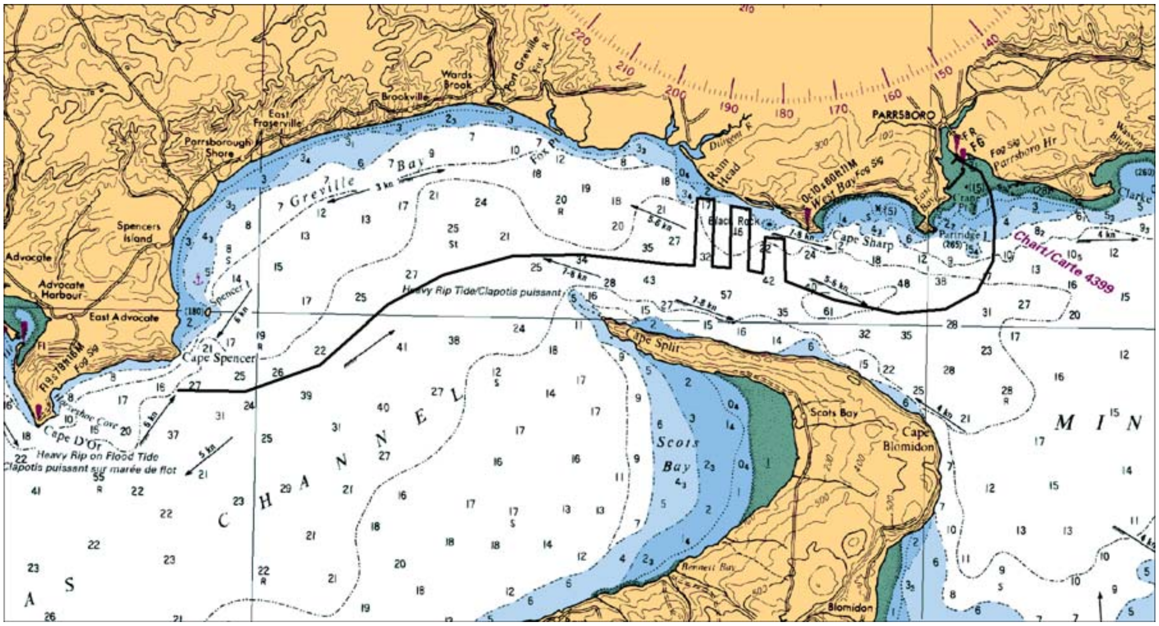

Figure 2b. Location of return survey route, ending in Parrsboro. Surveys based in Scots Bay (July and September) ended the survey off Parrsboro.

3. RESULTS AND DISCUSSION

3.1. Marine Mammals

Four species of marine mammals (Atlantic Harbour Porpoise (*Phocoena phoocena)*, Atlantic White-Sided Dolphin (*Lagenorhynchus acutus)*, Harbour Seal (*Phoca vitulina concolor*) and an unidentified whale), were observed in the surveys. Most sightings were in July-August, with several sightings in June (Table 1). Harbour Porpoise was most common and widely distributed in the study area; two sightings were made on the June survey, thirteen individuals were sighted in July, and six in August (Figure 3). Most of the Harbour Porpoise were sighted in groups, reaching eight individuals in one July sighting. Among the other observations were a pod of White-Sided Dolphin (15 individuals) and an unidentified whale in Minas Channel in August (an unidentified whale was observed in Minas Basin in July during one of the other surveys carried out in the area, Figure 3). A Harbour Seal was sighted near the demonstration site in June. These species may have been following fish movements in the area including a herring spawning migration into Minas Basin in June-July.

All the species observed are known to occur in the Bay of Fundy and were expected to occur in the study area, but their relative abundance and seasonal occurrence was unknown, as there were few previous recorded sightings for the area. Harbour Porpoise is a small porpoise found in Atlantic coastal areas in the summer to fall. The species is commonly taken as by-catch in gill nets, which may be presently threatening their survival (Caswell et al. 1998). The Northwest Atlantic population of the species is listed as a Species of Concern under the Species at Risk Act. Harbour Seal is a small coastal seal species, which can occur in offshore waters throughout Atlantic Canada year-round. Atlantic White-Sided Dolphin is a common Northwest Atlantic species, common in nearshore waters from June to September.

Table 1. Marine mammal observations during seabird and marine mammal surveys, Minas Basin, Minas Passage and Minas Channel, June – September 2009.

Date	Time (ADT)	Location	Species	Number of Animals
June 17, 2009	10:50	45 23.33 64 31.50	Harbour Porpoise	1
	15:15	45 22.58 64 26.09	Harbour Seal	1
	16:40	45 20.33 64 22.43	Harbour Porpoise	1
July 17, 2009	9:45	45 22.47 64 25.43	Harbour Porpoise	2
	14:00	45 17.99 64 41.93	Harbour Porpoise	2
	15:35	45 20.70 64 35.90	Harbour Porpoise	1
	16:25	45 21.37 64 30.24	Harbour Porpoise	8
August 16, 2009	10:00	45 21.31 64 26.05	Harbour Porpoise	5
	11:10	45 23.21 64 34.28	White-Sided Dolphin	15
	11:25	45 22.49 64 36.35	Unknown Whale	1
	18:05	45 20.02 64 17.21	Harbour Porpoise	1

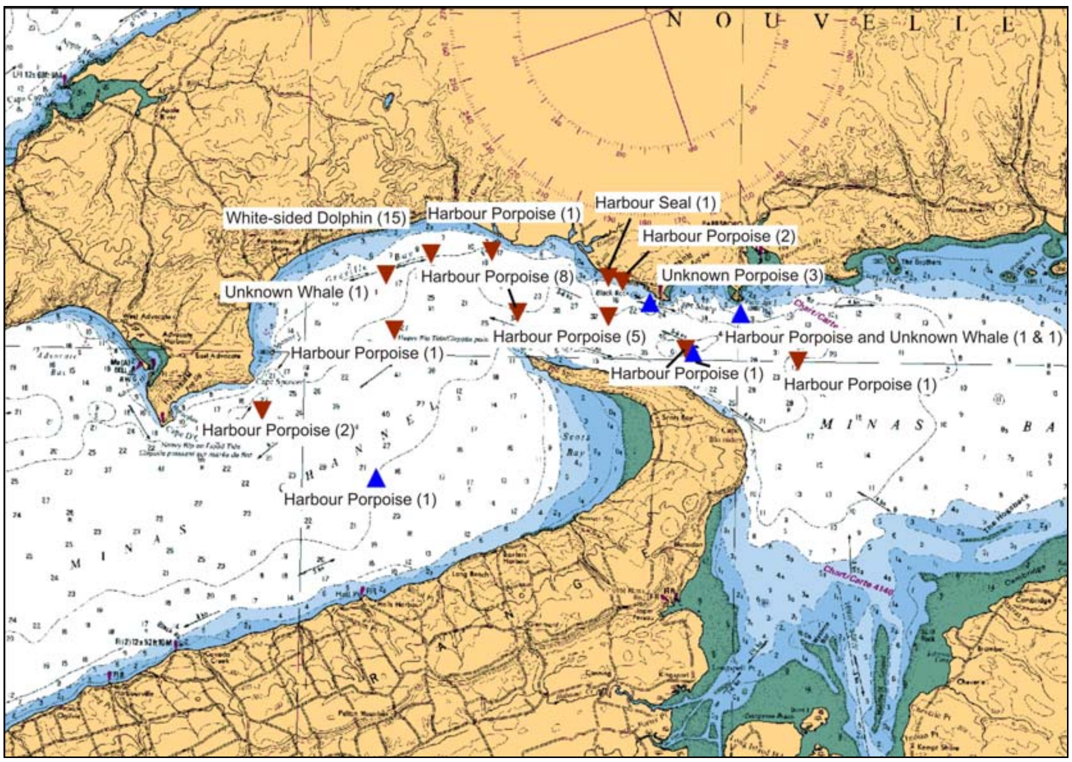

Figure 3. Sightings of marine mammals, June to September, 2009. Red triangles = sightings during survey; blue triangles = incidental observations, other surveys.

3.2. Seabirds, Waterfowl and Shorebirds

3.2.1. Survey Effort

Measures of seabird and marine mammal abundance as well as species diversity are influenced by sampling effort. Total numbers observed, as well as number of species occurring (species diversity), are positively correlated with sampling effort, while the quality of abundance estimates (e.g. numbers per kilometer or numbers per unit area) are typically improved by additional sampling effort. Important variations in sampling effort in the present survey included: differences in effort between areas, and differences in intensity of sampling (number of observation periods per unit distance or unit area). In the present study, there were differences in effort between Minas Basin and the other areas (Minas Basin lower and Minas Passage and Minas Channel with a similar level of sampling effort (Figures 4 & 5 and Table 2)) (due to the shorter distance traveled in Minas Basin) and between months, with June and September having a lower sampling effort than July and August (when the observer made more frequent observations). Due to differences in sampling effort, statistical comparisons and actual differences identified between Minas Passage and Minas Channel in terms of all measures would tend to be more likely to be detected by the statistical tests than between these areas and Minas Basin. Observations from Minas Basin would be expected to have higher variability than the other areas in terms of density estimates, and estimates of species diversity (i.e. the number of species detected would tend to be lower). These differences introduced by sampling effort would tend to obscure the natural differences between these areas that the analyses are trying to detect.

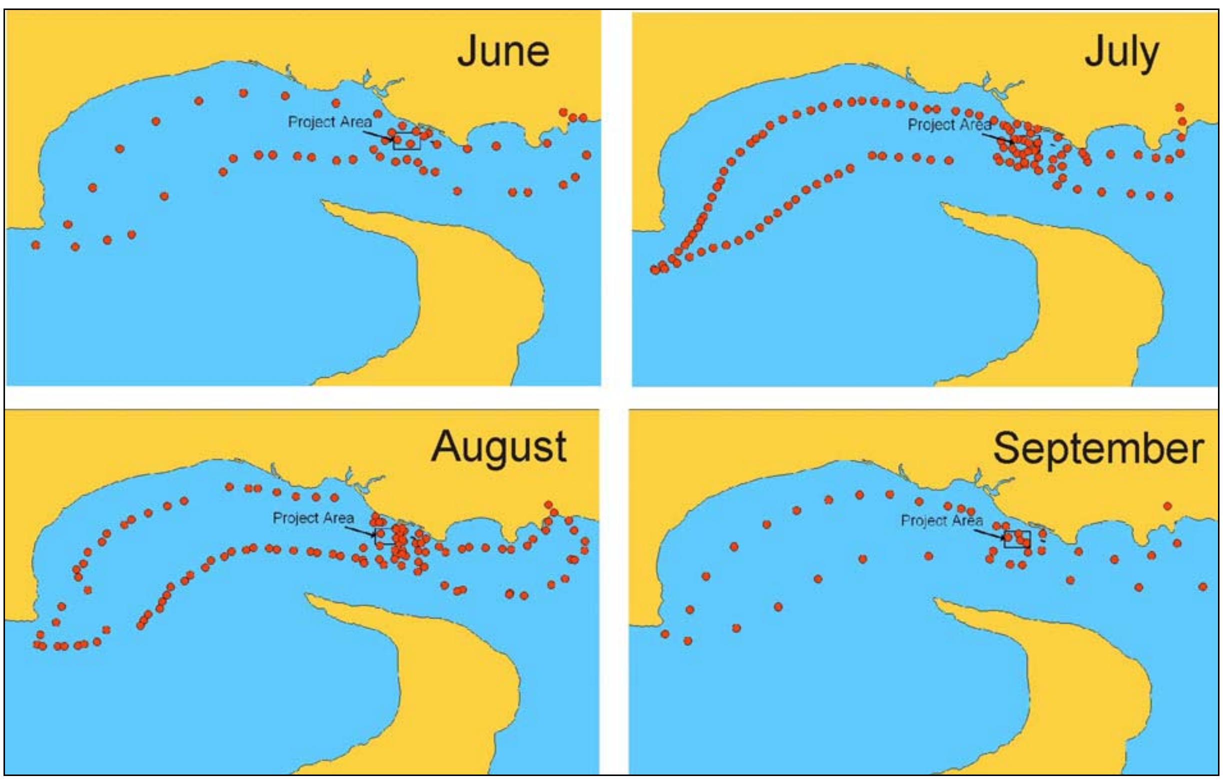

Figure 4. Locations of start points for 5-minute observation periods during seabird and waterfowl survey, June to September 2009, following route shown in Figure 2.

Table 2. Observation Effort, Seabird and Marine Mammal Survey of Minas Basin, Minas Passage and Minas Channel, June to September, 2009.					
		Distance Traveled (km)			
	Overall	June	July	August	September
Minas Basin	56.57	8.97	16.30	23.85	7.45
Minas Passage	99.92	18.20	37.48	32.51	11.73
Minas Channel	104.47	14.33	41.54	35.15	13.45
Total	260.96	41.50	95.33	91.51	32.63
	Overall	Area Sampled[1] (km^2)			
Minas Basin	16.97	2.69	4.89	7.16	2.23
Minas Passage	29.98	5.46	11.25	9.75	3.52
Minas Channel	31.34	4.30	12.46	10.55	4.04
Total	78.29	12.45	28.60	27.45	9.79
	Overall	Number of Observations (5-minute periods)			
Minas Basin	63	10	16	29	8
Minas Passage	123	22	42	43	16
Minas Channel	137	18	58	45	16
Total	323	50	116	117	40
1. Observations 'in transect' (i.e. within 300 m band parallel to one side of vessel).					

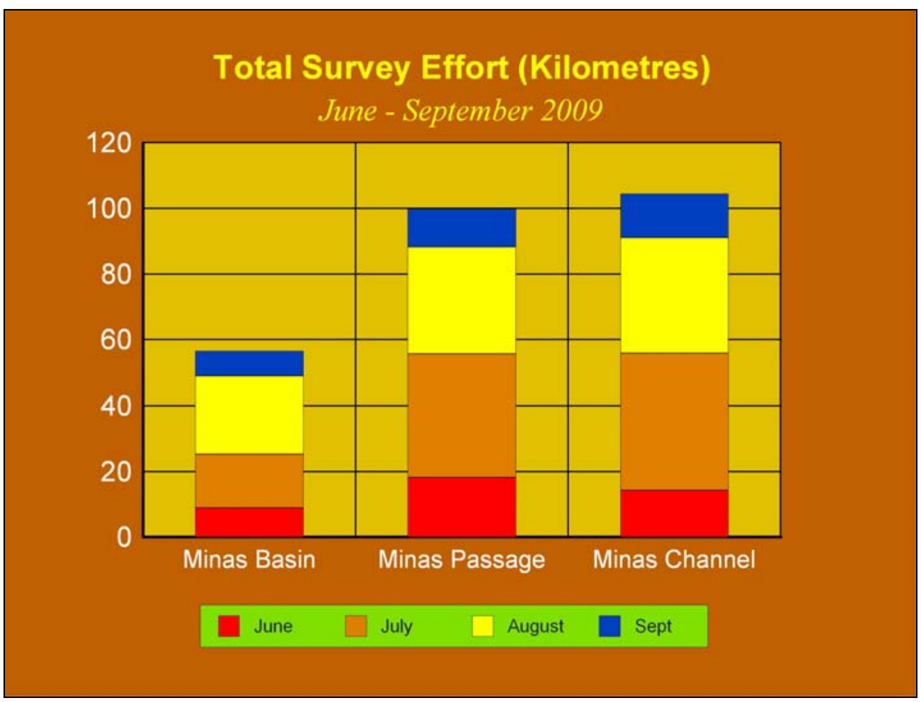

Figure 5. Distance surveyed (kilometres), June to September, 2009.

3.2.2. Species Composition

Overall, 395 seabirds, waterfowl and shorebirds[4] in twelve species were sighted during the survey (Figure 6 & Table 3). Most sightings were in Minas Passage, and the lowest numbers were observed in Minas Basin (Figure 6). Herring Gull (*Larus argentatus)* was the most abundant and common (occurring in 38.5 % of observation periods, Table 2) and dominated abundance in July and August (Table 3, Figures 7 & 8). Common eider (*Somateria molissima*), a coastal seaduck species was next in abundance, dominating in the June and September surveys, largely due to localized high abundances in flocks, and was not common (only 1.9 % of observation periods overall, Table 2). Great Black-backed Gull (*Larus marinus*) ranked third in abundance overall and in frequency of occurrence (6.5 % of observation periods). The remaining species were present in low numbers overall and occurred infrequently. Black Guillemot (*Ceppheus grille*), Common Loon (*Gavia immer*), and Double-crested Cormorant (*Phalacrocorax auritus*) were observed in all the surveys, and incidental occurrences were recorded of Ring-billed Gull (*Larus delawarensis*, August & September), Greater Shearwater (*Puffinus gravis*, July), Northern Gannet (*Morus bassanus*, August), Red Phalarope (*Phalaropus fulicaria*, July), Pacific Loon (*Gavia pacifica*, June), and White-winged Scoter (*Melanitta fusca*, September)(Figures 7 & 8).

Two terrestrial species were observed—two immature Ruby-Throated Hummingbirds were sighted in one observation period on the outgoing survey in August in Minas Basin off Partridge Island between Parrsboro and Cape Sharp; an immature Bald Eagle was seen about 600 m south of Black Rock, also in August.

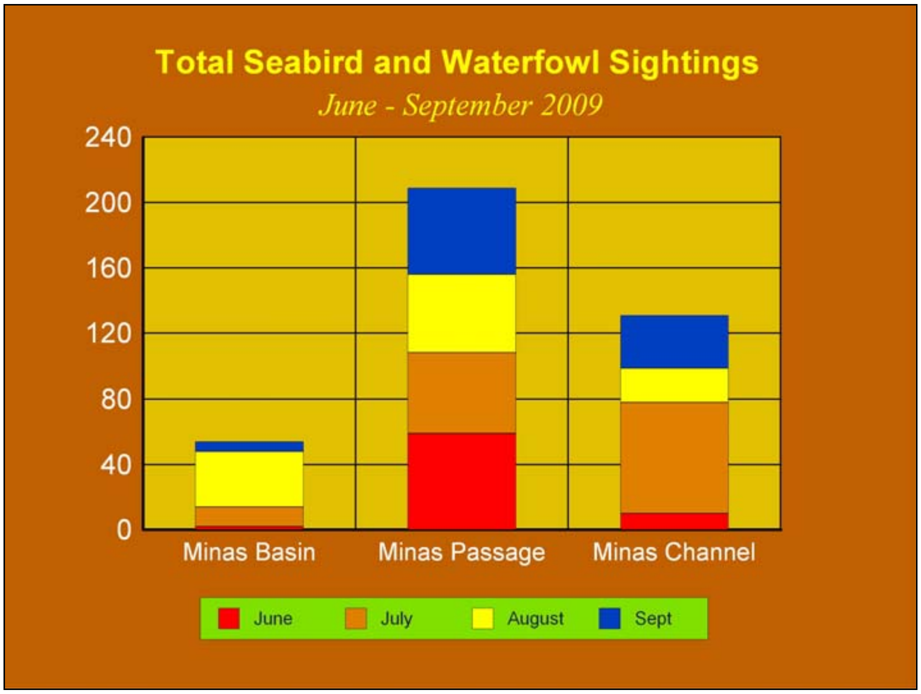

Figure 6. Summary of numbers of sightings of seabirds and waterfowl by area and month, June to September, 2009.

[4] Red Phalarope, a shorebird species, was observed in July.

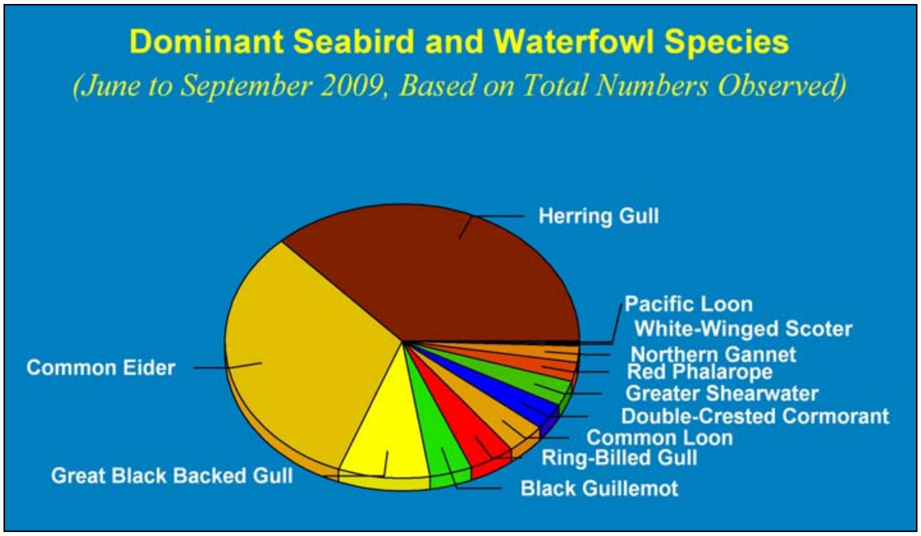

Figure 7. Species composition and relative abundance of seabird and waterfowl species observed in Minas Basin, Minas Passage and Minas Channel, June-September, 2009.

3.2.3. Distribution and Abundance

Overall Abundance

Overall abundance of seabirds and waterfowl expressed either per square kilometre or per kilometer showed a seasonal pattern of higher abundances in July and August than in other months, with June lowest, but generally without a regional pattern (Figures 9-12). Highest average abundance reached 3.8 birds per km^2 in Minas Channel in July and was lowest in Minas Passage in June (0.2 birds per km^2); these are lower than abundances on the New Brunswick side of the outer Bay of Fundy where abundances of 10-13.9 birds/ per km^2 have been recorded, but higher than the Nova Scotia side of the Bay in the Digby Gut area (0.01-0.09 birds per km^2)(Lock et al. 1994). Abundance per kilometer was influenced by localized occurrences of Common Eider, which account for high abundances per kilometre in June and September in Minas Passage and in Minas Channel in September (just west of the Minas Passage boundary)(Tables 4-7, Figure 9). Eiders commonly congregate near Black Rock and in adjacent waters, and in this case, several large flocks were observed near the tidal project site. Elevated density per km^2 in Minas Channel in June and in Minas Basin in September (Figure 10) corresponded to more sightings of Herring Gulls in those surveys. The higher density per unit area found in Minas Channel compared to Minas Passage in June (Figure 10) was statistically significant (Kruskal Wallace One-Way Analysis of Variance, $p<0.01$)[5]. In August the difference in density per km^2 between Minas Passage and Minas Channel (Minas Passage higher) was also statistically significant ($p<0.05$). Only the difference in abundance per kilometer between Minas Passage and Minas Channel in August (Minas Passage higher) was significant ($p<0.01$) although several of the other comparisons had probabilities of significance around or below $p<0.1$.

[5] All further mention of statistical significance refers to the Kruskal-Wallace test.

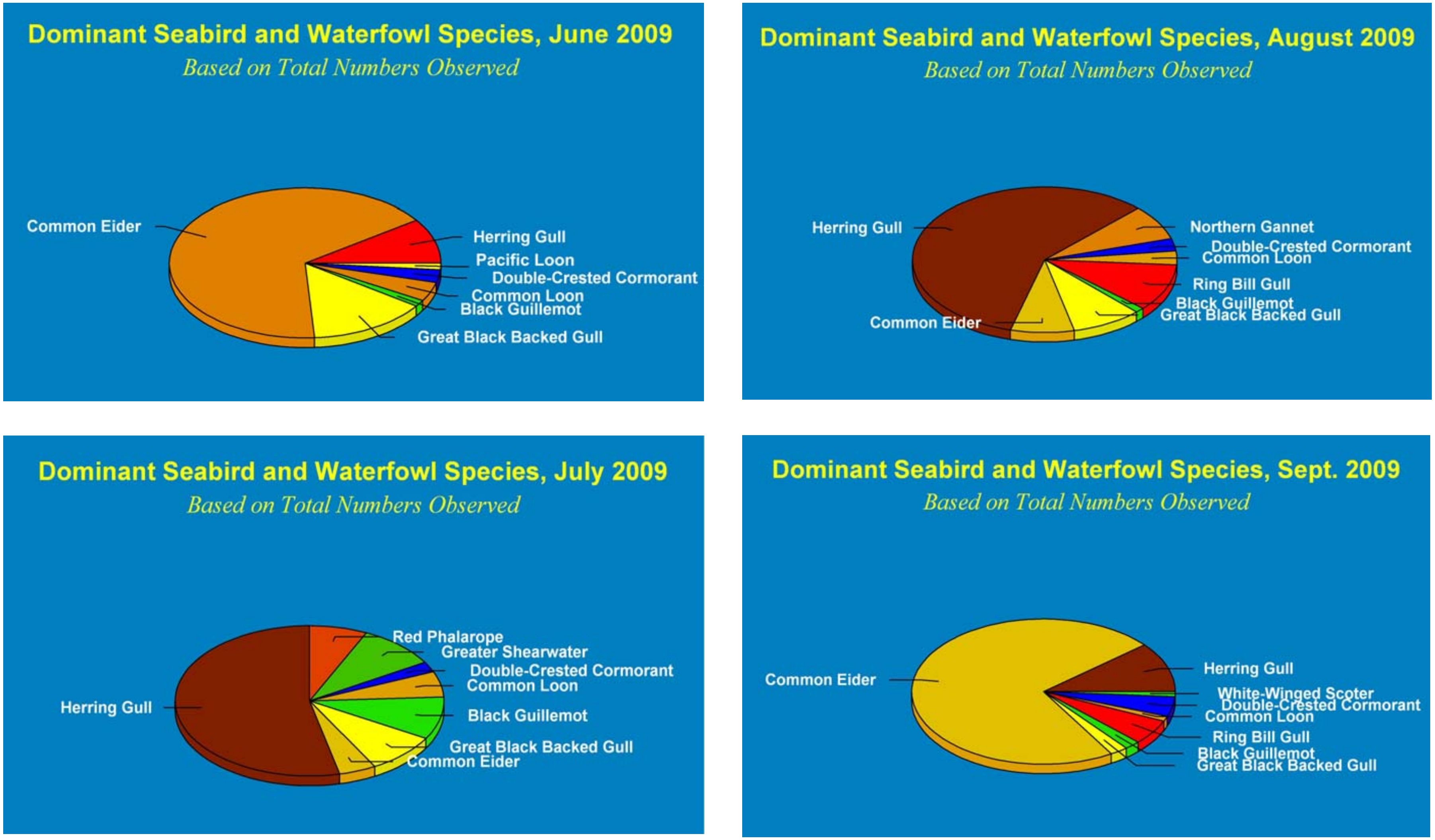

Figure 7. Species composition and relative abundance of seabird and waterfowl species by month, Minas Basin, Minas Passage and Minas Channel, June to September 2009.

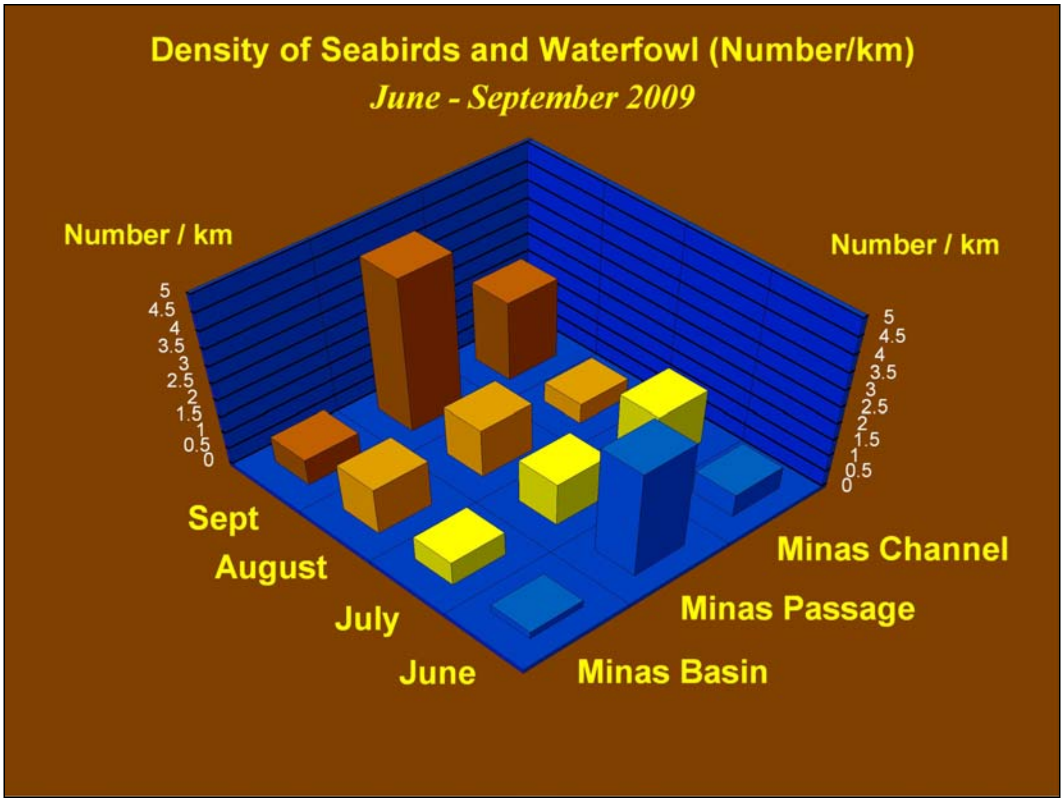

Figure 9. Abundance of seabirds and waterfowl (number/kilometer), June to September, 2009.

Seasonal differences included: the difference between June and August in birds per kilometer in Minas Basin (August abundance higher) ($p < 0.10$)[6]; and statistically significant differences in Minas Passage between months overall in density per km^2 ($p<0.001$)(density was high in July, low in June and medium in August and September, Figure 10), in particular for the June and the July-August measures (July and August higher, $p < 0.001$ and $p<0.01$ respectively), and between July and the August and September measures (July higher, $p < 0.05$ for both comparisons). Similar to the comparison between months overall, the estimate of total abundance per kilometer in Minas Passage differed marginally between July and August (July higher, $p < 0.1$). In Minas Channel, significant differences were observed between months overall ($p<0.001$), reflecting a relatively higher abundance in June and July and low in August-September. Abundance per kilometer also showed statistically significant differences between months ($p< 0.01$), with highest abundance in July and September. Overall abundance per km^2 was higher in June than

[6] Comparisons included: between months overall and between pairs of months individually.

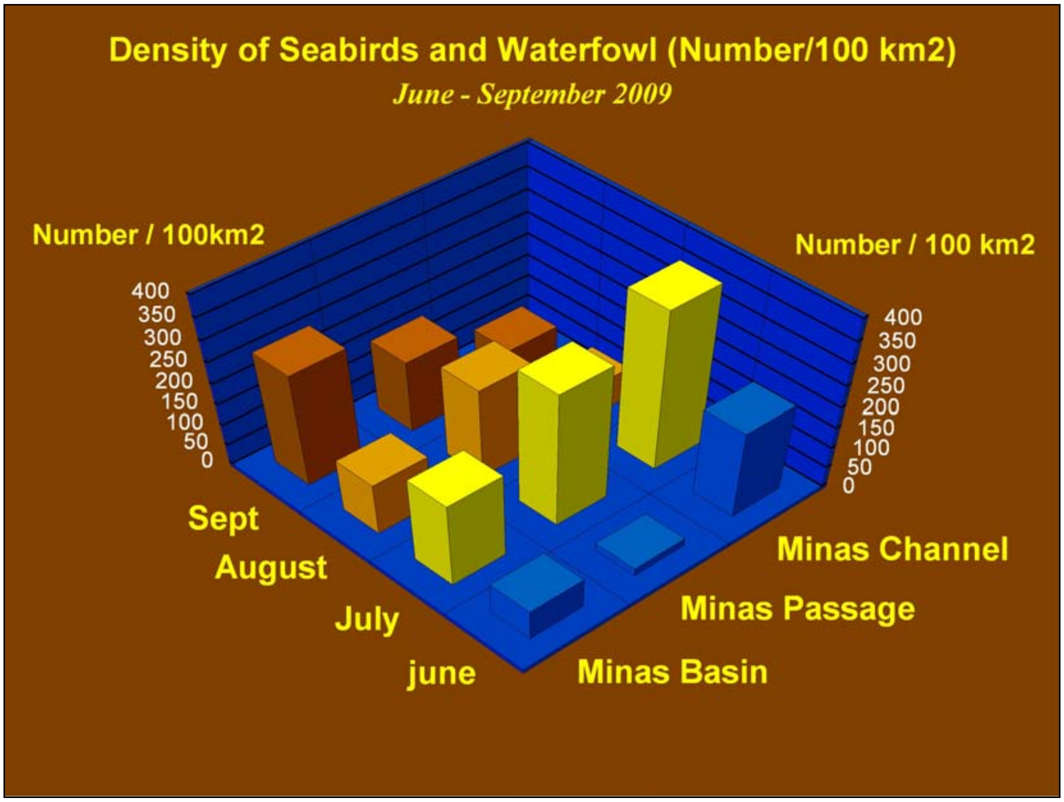

Figure 10. Abundance of seabirds and waterfowl (number/100 km^2), June to September 2009.

in August ($p<0.05$), and higher in July than compared with either August or September ($p<0.001$ and $P<0.05$ respectively). In contrast, overall abundance per kilometer was higher in July than in June and August ($p<0.059$ and $p<0.05$ respectively). Although overall bird density per km^2 was significantly higher in July than in September, only the difference in abundance per kilometer was (higher in September than in July) was statistically significant ($p<0.05$).

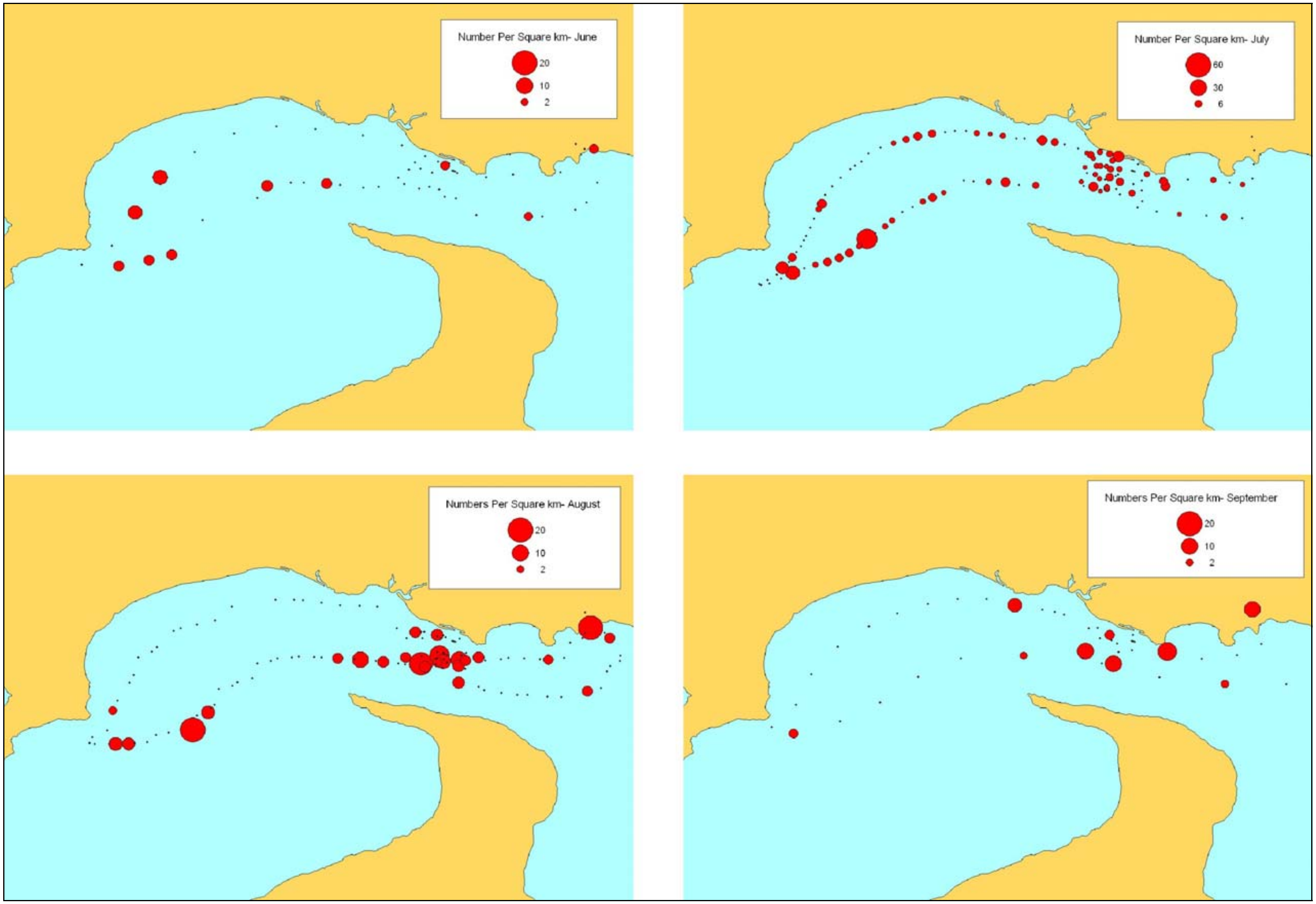

Figure 11. Overall density of seabirds and waterfowl (number per km^2) in Minas Basin, Minas Passage and Minas Channel, June to September, 2009.

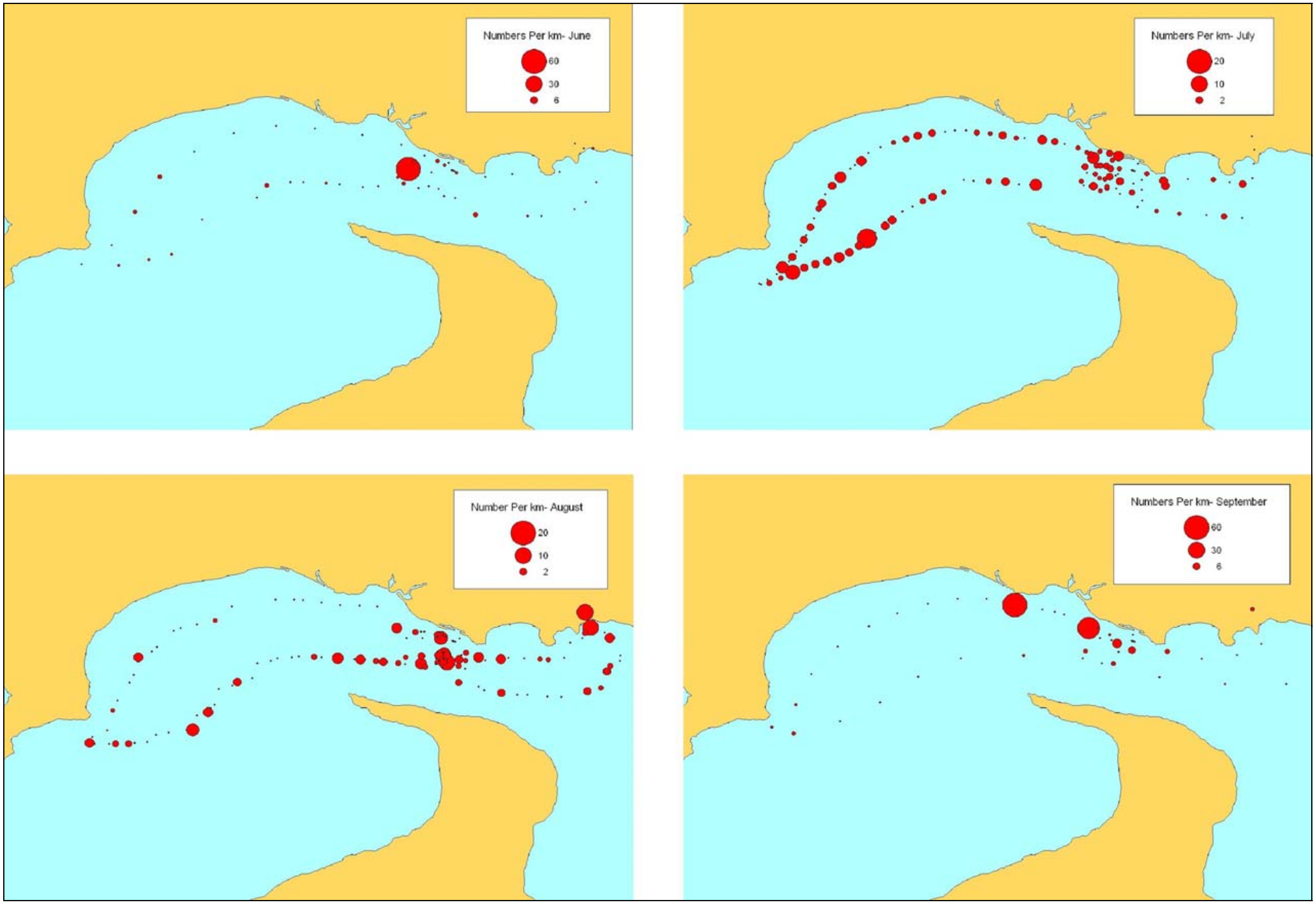

Figure 12. Overall abundance of seabirds and waterfowl (number per kilometre) in Minas Basin, Minas Passage and Minas Channel, June to September, 2009.

Table 3. Abundance of seabirds in the vicinity of the Fundy Tidal Energy Demonstration Site, June to September, 2009. Number of 5-minute observation periods: Minas Basin = 63; Minas Passage = 123; Minas Channel = 137.

Area	Total, All Species	Great Black-Backed Gull	Double-Crested Cormorant	Herring Gull	Common Loon	Common Eider	Black Guillemot	Pacific Loon	Greater Shearwater	Northern Gannet	Red Phalarope	Ring-Billed Gull	White-Winged Scoter
	Total Number Observed												
Minas Basin	54	5	3	30	3	2	4	1	1	0	0	5	0
Minas Passage	209	18	7	59	4	100	4	0	2	5	0	10	0
Minas Channel	132	9	2	57	7	25	8	0	9	4	9	1	1
Total	395	32	12	146	14	127	16	1	12	9	9	16	1
	Number / Kilometre												
Minas Basin	0.95	0.09	0.05	0.53	0.05	0.04	0.07	0.02	0.02	0.00	0.00	0.09	0.00
Minas Passage	2.09	0.18	0.07	0.59	0.04	1.00	0.04	0.00	0.02	0.05	0.00	0.10	0.00
Minas Channel	1.26	0.09	0.02	0.55	0.07	0.24	0.08	0.00	0.09	0.04	0.09	0.01	0.01
Overall	1.51	0.12	0.05	0.56	0.05	0.49	0.06	0.00	0.05	0.03	0.03	0.06	0.00
	Number Observed within 300 m of Survey Vessel												
Minas Basin	27	1	0	17	3	2	2	1	1	0	0	0	0
Minas Passage	64	5	1	39	1	3	2	0	2	2	0	9	0
Minas Channel	67	8	0	38	5	0	0	0	7	0	9	0	0
Total	158	14	1	94	9	5	4	1	10	2	9	9	0
	Number of Seabirds per / 100 km^2												
Minas Basin	159.10	5.89	0.00	100.17	17.68	11.78	11.78	5.89	5.89	0.00	0.00	0.00	0.00
Minas Passage	213.51	16.68	3.34	130.11	3.34	10.01	6.67	0.00	6.67	6.67	0.00	30.02	0.00
Minas Channel	213.78	25.53	0.00	121.25	15.95	0.00	0.00	0.00	22.33	0.00	28.72	0.00	0.00
Overall	201.82	17.88	1.28	120.07	11.50	6.39	5.11	1.28	12.77	2.55	11.50	11.50	0.00
Month	Observations	Frequency of Occurrence (% of observation periods)											
June	50	12.0	4.0	12.0	4.0	2.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0
July	116	6.0	2.6	45.7	2.6	1.7	0.9	0.0	10.3	0.9	0.9	0.0	0.0
August	117	5.1	1.7	29.9	0.9	2.6	0.9	0.0	0.0	4.3	0.0	6.8	0.0
September	40	5.0	5.0	15.0	2.5	7.5	2.5	0.0	0.0	0.0	0.0	7.5	2.5
Overall	323	6.5	2.7	38.5	2.6	1.9	1.0	0.3	7.5	1.2	0.6	0.8	0.0

Table 4. Abundance of seabirds in the vicinity of the Fundy Tidal Energy Demonstration Site, June 16, 2009. Numbers in brackets indicate number which were immature or juvenile individuals. Number of 5-minute observation periods: Minas Basin = 10; Minas Passage = 22; Minas Channel = 18.

Area	Total, All Species	Great Black -Backed Gull	Double-Crested Cormorant	Herring Gull	Common Loon	Common Eider	Black Guillemot	Pacific Loon	Greater Shearwater	Northern Gannet	Red Phalarope	Ring-Billed Gull	White-Winged Scoter
	Total Number Observed												
Minas Basin	2	1	0	0	0	0	0	1 (1)	0	0	0	0	0
Minas Passage	59	7	2	0	2 (2)	47 (9)	1	0	0	0	0	0	0
Minas Channel	10	2	0	7 (2)	1	0	0	0	0	0	0	0	0
Total	71	10	2	7	3	47	1	1	0	0	0	0	0
	Number / Kilometre												
Minas Basin	0.22	0.11	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00
Minas Passage	3.24	0.38	0.11	0.00	0.11	2.58	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Minas Channel	0.70	0.14	0.00	0.49	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Overall	1.71	0.24	0.05	0.17	0.07	1.13	0.02	0.02	0.00	0.00	0.00	0.00	0.00
	Number Observed within 300 m of Survey Vessel												
Minas Basin	2	1	0	0	0	0	0	1	0	0	0	0	0
Minas Passage	1	0	1	0	0	0	0	0	0	0	0	0	0
Minas Channel	9	2	0	7	0	0	0	0	0	0	0	0	0
Total	12	3	1	7	0	0	0	1	0	0	0	0	0
	Number of Seabirds per / 100 km^2												
Minas Basin	74.35	37.17	0.00	0.00	0.00	0.00	0.00	37.17	0.00	0.00	0.00	0.00	0.00
Minas Passage	18.31	0.00	18.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Minas Channel	209.39	46.53	0.00	162.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Overall	96.40	24.10	8.03	56.23	0.00	0.00	0.00	8.03	0.00	0.00	0.00	0.00	0.00

Table 5. Abundance of seabirds in the vicinity of the Fundy Tidal Energy Demonstration Site, July 17, 2009. Numbers in brackets indicate number, which were immature or juvenile individuals. Number of 5-minute observation periods: Minas Basin = 16; Minas Passage = 42; Minas Channel = 58.

Area	Total, All Species	Great Black -Backed Gull	Double-Crested Cormorant	Herring Gull	Common Loon	Common Eider	Black Guillemot	Pacific Loon	Greater Shearwater	Northern Gannet	Red Phalarope	Ring-Billed Gull	White-Winged Scoter
	Total Number Observed												
Minas Basin	12	1	0	7	0	2	1	0	1 (1)	0	0	0	0
Minas Passage	49	7 (3)	1	31	1 (1)	4 (4)	3	0	2 (2)	0	0	0	0
Minas Channel	69	3	2	31 (6)	6 (6)	0	8	0	9 (6)	1 (1)	9 (9)	0	0
Total	130	11	3	69	7	6	12	0	12	1	9	0	0
	Number / Kilometre												
Minas Basin	0.74	0.06	0.00	0.43	0.00	0.12	0.06	0.00	0.06	0.00	0.00	0.00	0.00
Minas Passage	1.31	0.19	0.03	0.83	0.03	0.11	0.08	0.00	0.05	0.00	0.00	0.00	0.00
Minas Channel	1.66	0.07	0.05	0.75	0.14	0.00	0.19	0.00	0.22	0.02	0.22	0.00	0.00
Overall	1.36	0.12	0.03	0.72	0.07	0.06	0.13	0.00	0.13	0.01	0.09	0.00	0.00
	Number Observed within 300 m of Survey Vessel												
Minas Basin	10	0	0	7	0	2	0	0	1	0	0	0	0
Minas Passage	36	3	0	28	1	0	2	0	2	0	0	0	0
Minas Channel	47	3	0	23	5	0	0	0	7	0	9	0	0
Total	93	6	0	58	6	2	2	0	10	0	9	0	0
	Number of Seabirds per / 100 km^2												
Minas Basin	204.47	0.00	0.00	143.13	0.00	40.89	0.00	0.00	20.45	0.00	0.00	0.00	0.00
Minas Passage	320.13	26.68	0.00	248.99	8.89	0.00	17.79	0.00	17.79	0.00	0.00	0.00	0.00
Minas Channel	377.14	24.07	0.00	184.56	40.12	0.00	0.00	0.00	56.17	0.00	72.22	0.00	0.00
Overall	325.19	20.98	0.00	202.81	20.98	6.99	6.99	0.00	34.97	0.00	31.47	0.00	0.00

Table 6. Abundance of seabirds in the vicinity of the Fundy Tidal Energy Demonstration Site, August 16 2009. Numbers in brackets indicate number, which were immature or juvenile individuals. Number of 5-minute observation periods: Minas Basin = 29; Minas Passage = 43; Minas Channel = 45.

Area	Total, All Species	Great Black -Backed Gull	Double-Crested Cormorant	Herring Gull	Common Loon	Common Eider	Black Guillemot	Pacific Loon	Greater Shearwater	Northern Gannet	Red Phalarope	Ring-Bill Gull	White-Winged Scoter
	Total Number Observed												
Minas Basin	34	3	3	19 (3)	3 (2)	0	1	0	0	0	0	5 (1)	0
Minas Passage	48	3	0	26 (7)	0	8	0	0	0	5 (4)	0	6 (1)	0
Minas Channel	21	3 (1)	0	15 (4)	0	0	0	0	0	3 (3)	0	0	0
Total	103	9	3	60	3	8	1	0	0	8	0	11	0
	Number / Kilometre												
Minas Basin	1.43	0.13	0.13	0.80	0.13	0.00	0.04	0.00	0.00	0.00	0.00	0.21	0.00
Minas Passage	1.48	0.09	0.00	0.80	0.00	0.25	0.00	0.00	0.00	0.15	0.00	0.18	0.00
Minas Channel	0.60	0.09	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00
Overall	0.61	0.05	0.02	0.36	0.02	0.05	0.01	0.00	0.00	0.05	0.00	0.07	0.00
	Number Observed within 300 m of Survey Vessel												
Minas Basin	9	0	0	6	3	0	0	0	0	0	0	0	0
Minas Passage	21	2	0	10	0	2	0	0	0	2	0	5	0
Minas Channel	8	3	0	5	0	0	0	0	0	0	0	0	0
Total	38	5	0	21	3	2	0	0	0	2	0	5	0
	Number of Seabirds per / 100 km^2												
Minas Basin	125.78	0.00	0.00	83.85	41.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Minas Passage	215.35	20.51	0.00	102.55	0.00	20.51	0.00	0.00	0.00	20.51	0.00	51.27	0.00
Minas Channel	75.86	28.45	0.00	47.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Overall	138.42	18.21	0.00	76.50	10.93	7.29	0.00	0.00	0.00	7.29	0.00	18.21	0.00

Table 7. Abundance of seabirds in the vicinity of the Fundy Tidal Energy Demonstration Site, September 13, 2009. Numbers in brackets indicate number, which were immature or juvenile individuals. Number of 5-minute observation periods: Minas Basin = 8; Minas Passage = 16; Minas Channel = 16.

Area	Total, All Species	Great Black -Backed Gull	Double-Crested Cormorant	Herring Gull	Common Loon	Common Eider	Black Guillemot	Pacific Loon	Greater Shearwater	Northern Gannet	Red Phalarope	Ring-Billed Gull	White-Winged Scoter
	Total Number Observed												
Minas Basin	6	0	0	4 (2)	0	0	2 (1)	0	0	0	0	0	0
Minas Passage	53	1 (1)	4 (3)	2 (1)	1 (1)	41 (33)	0	0	0	0	0	4 (3)	0
Minas Channel	32	1 (1)	0	4 (2)	0	25 (25)	0	0	0	0	0	1	1
Total	91	2	4	10	1	66	2	0	0	0	0	5	1
	Number / Kilometre												
Minas Basin	0.81	0.00	0.00	0.54	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00
Minas Passage	4.52	0.09	0.34	0.17	0.09	3.50	0.00	0.00	0.00	0.00	0.00	0.34	0.00
Minas Channel	2.38	0.07	0.00	0.30	0.00	1.86	0.00	0.00	0.00	0.00	0.00	0.07	0.07
Overall	2.79	0.06	0.12	0.31	0.03	2.02	0.06	0.00	0.00	0.00	0.00	0.15	0.03
	Number Observed within 300 m of Survey Vessel												
Minas Basin	6	0	0	4	0	0	2	0	0	0	0	0	0
Minas Passage	6	0	0	1	0	1	0	0	0	0	0	4	0
Minas Channel	3	0	0	3	0	0	0	0	0	0	0	0	0
Total	15	0	0	8	0	1	2	0	0	0	0	4	0
	Number of Seabirds per / 100 km^2												
Minas Basin	268.47	0.00	0.00	178.98	0.00	0.00	89.49	0.00	0.00	0.00	0.00	0.00	0.00
Minas Passage	170.54	0.00	0.00	28.42	0.00	28.42	0.00	0.00	0.00	0.00	0.00	113.70	0.00
Minas Channel	74.35	0.00	0.00	74.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Overall	153.25	0.00	0.00	81.73	0.00	10.22	20.43	0.00	0.00	0.00	0.00	40.87	0.00

Herring Gull

Herring Gull was the most abundant seabird overall and the most commonly observed in the study area. The species is a common annual breeder, nesting on islands and seacliffs along the Bay of Fundy. It is primarily a scavenger/ omnivore, which feeds at the water surface. Herring Gull abundance is often linked to human activities and associated food sources in coastal areas. Herring Gull occurred in all months but the highest number of sightings were made in July and August surveys (Tables 5 & 6, Figures 13-15). In Minas Passage, density per km^2 was significantly higher in July than August ($p<0.01$). Most individuals were adults with immatures and juveniles becoming increasingly important later in the season (June, 14.3%; July, 8.7 %, August, 23,3% and September, 50%) (Tables 4-7).

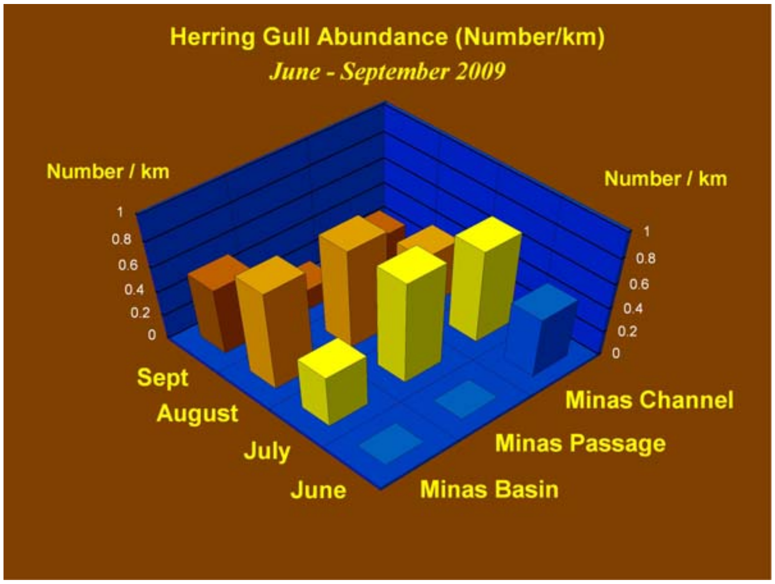

Figure 13. Abundance of Herring Gulls (number/kilometer), June to September, 2009.

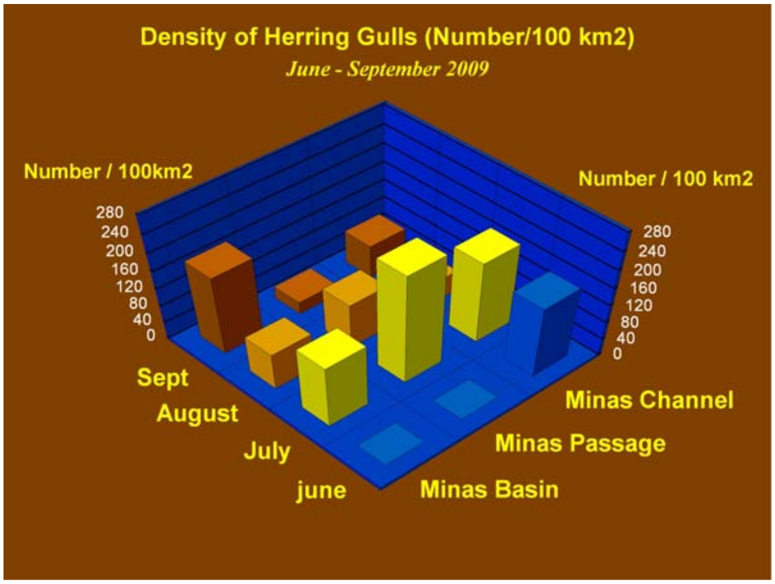

Figure 14. Density of Herring Gulls (number/100 km^2), June to September 2009.

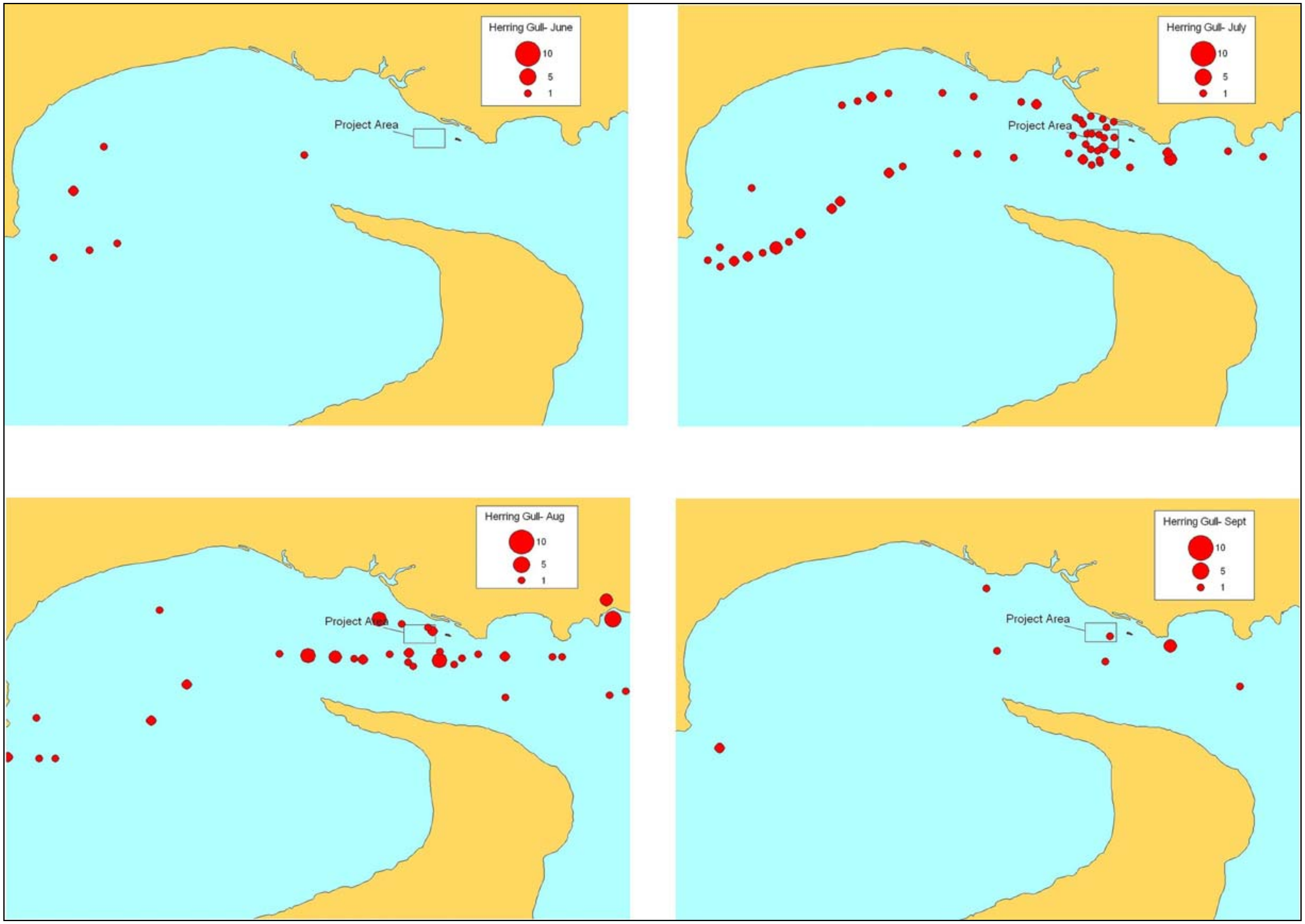

Figure 15. Distribution and abundance (individuals per 5-minute observation period) of Herring Gull in Minas Basin, Minas Passage and Minas Channel, June to September 2009. Area shown is Crown Lease which contains berths for tidal device installation.

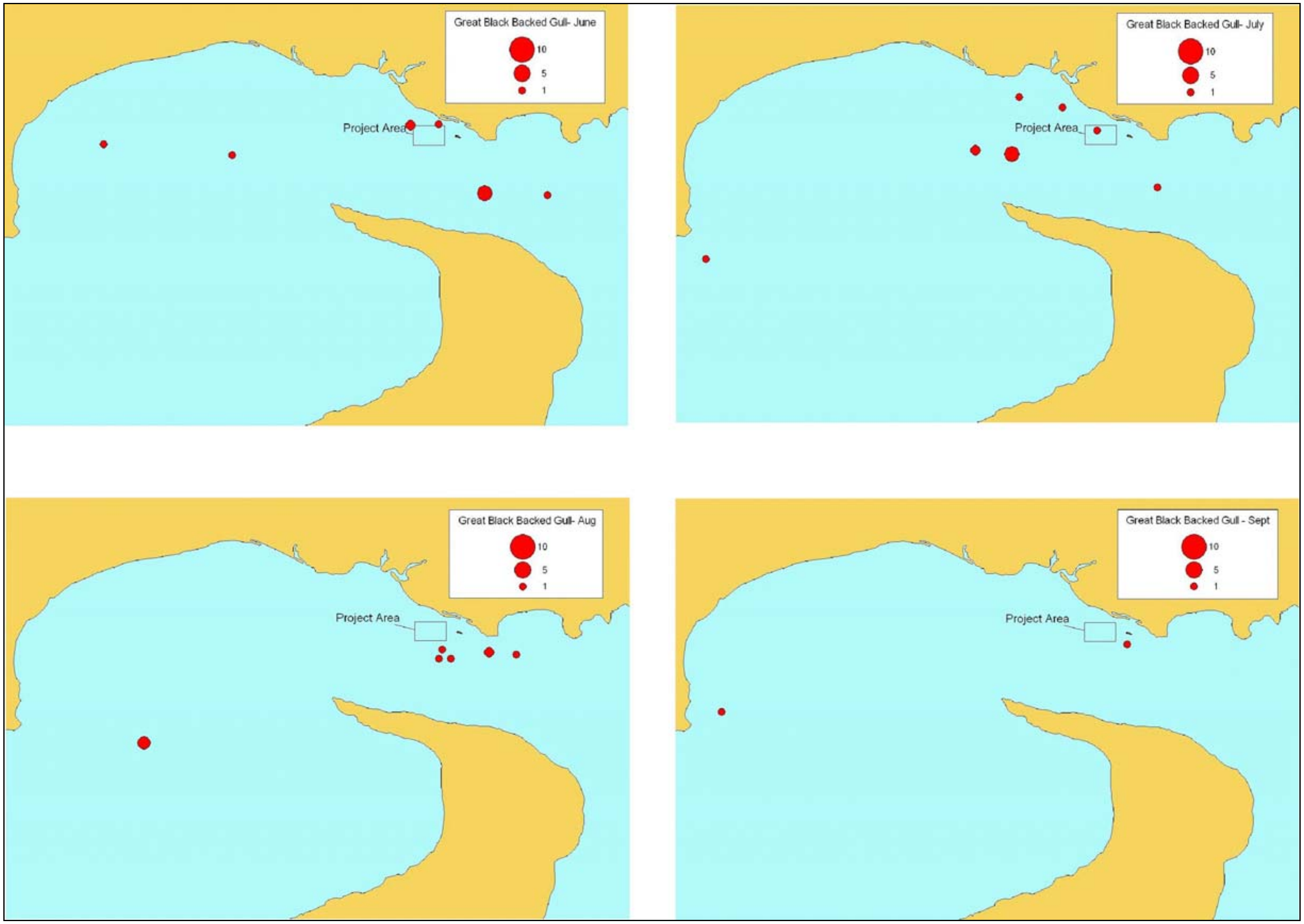

Figure 16. Distribution and abundance (individuals per 5-minute observation period) of Great Black-Backed Gull in Minas Basin, Minas Passage and Minas Channel, June to September 2009. Area shown is Crown Lease which contains berths for tidal device installation.

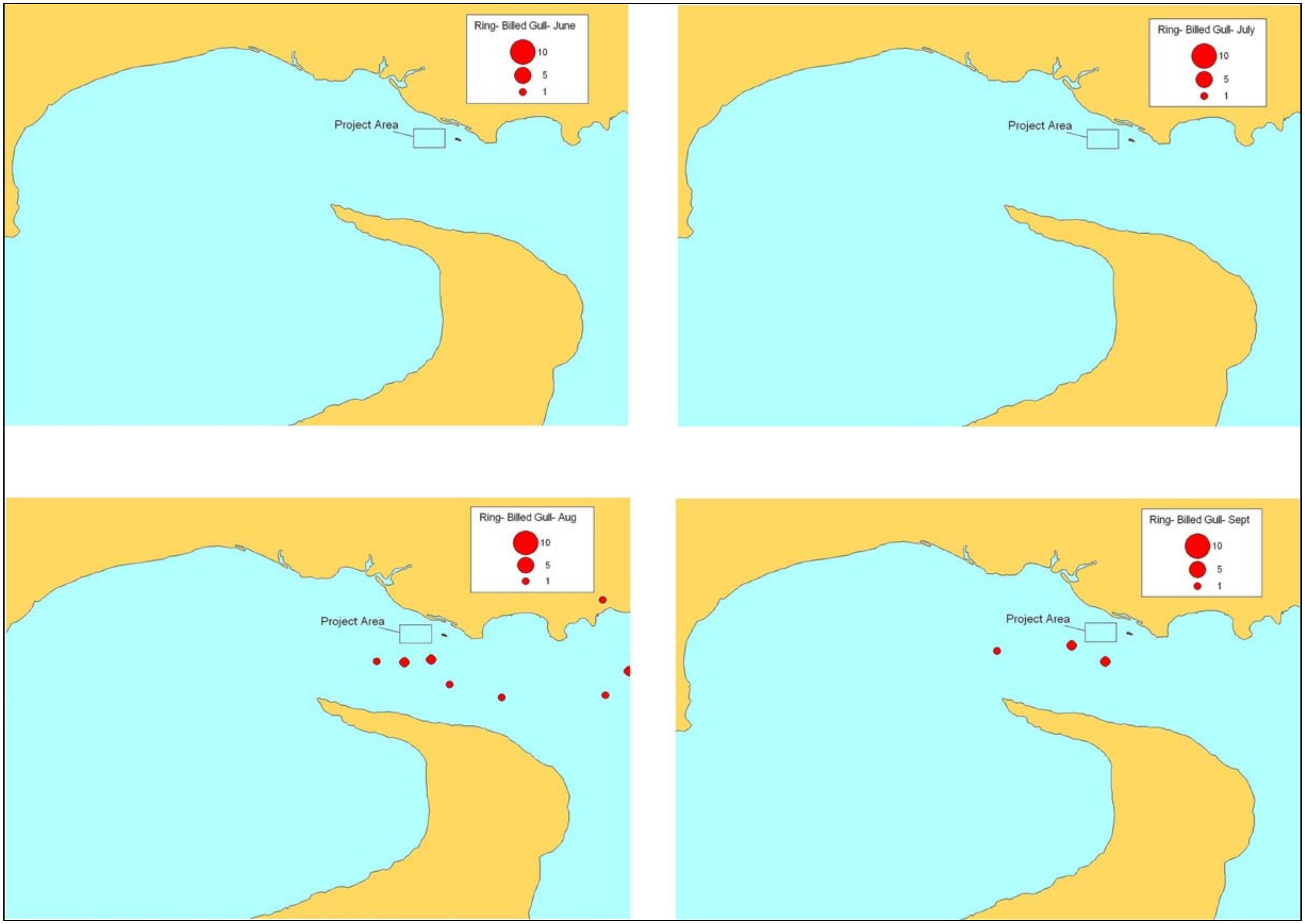

Figure 17. Distribution and abundance (individuals per 5-minute observation period) of Ring-Billed Gull in Minas Basin, Minas Passage and Minas Channel, June to September 2009. Area shown is Crown Lease which contains berths for tidal device installation.

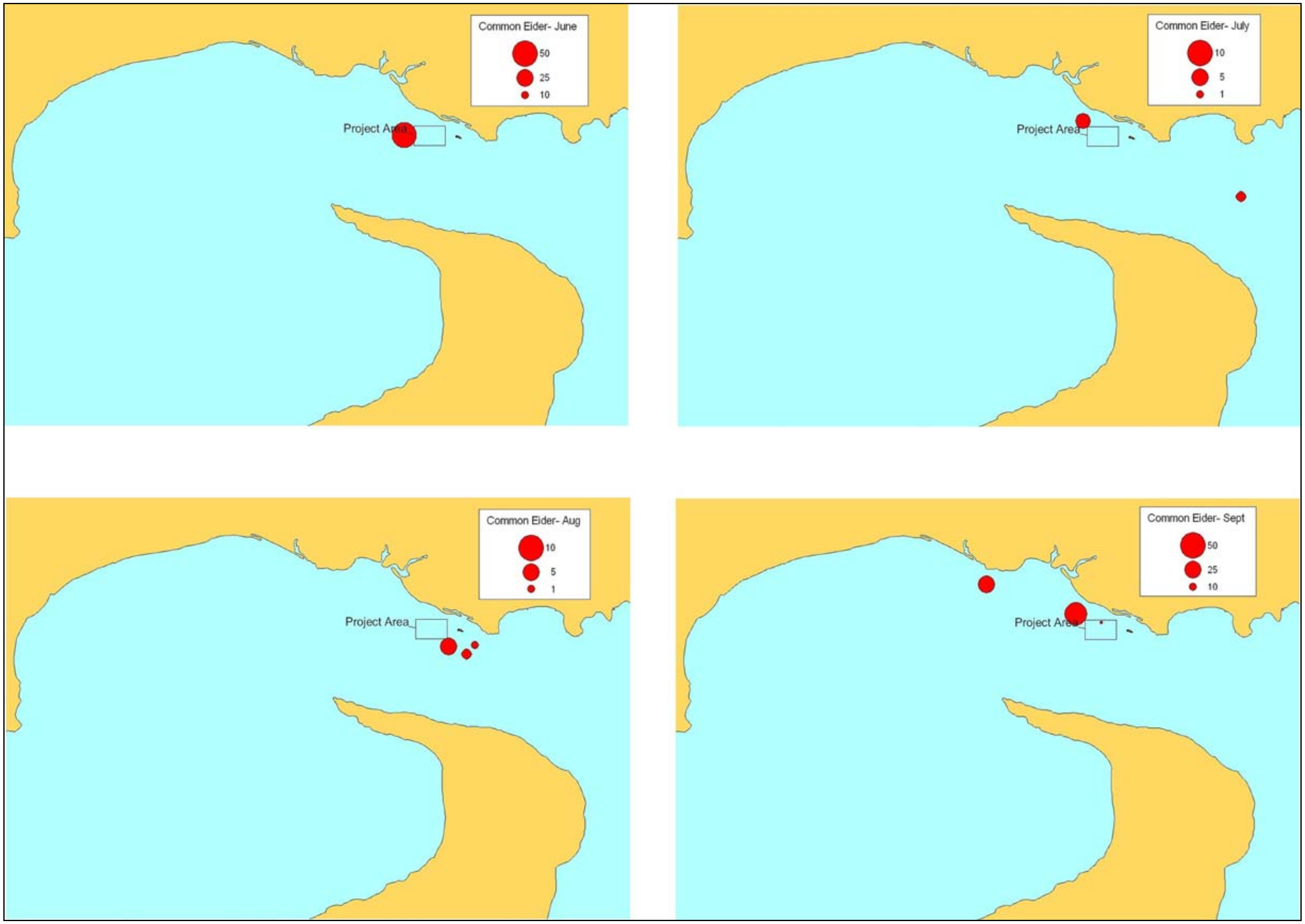

Figure 18. Distribution and abundance (individuals per 5-minute observation period) of Common Eider in Minas Basin, Minas Passage and Minas Channel, June to September 2009. Area shown is Crown Lease which contains berths for tidal device installation.

Figure 19. Distribution and abundance (individuals per 5-minute observation period) of Double Crested Cormorant in Minas Basin, Minas Passage and Minas Channel, June to September 2009. Area shown is Crown Lease which contains berths for tidal device installation.

Figure 20. Distribution and abundance (individuals per 5-minute observation period) of Northern Gannet in Minas Basin, Minas Passage and Minas Channel, June to September 2009. Area shown is Crown Lease which contains berths for tidal device installation.

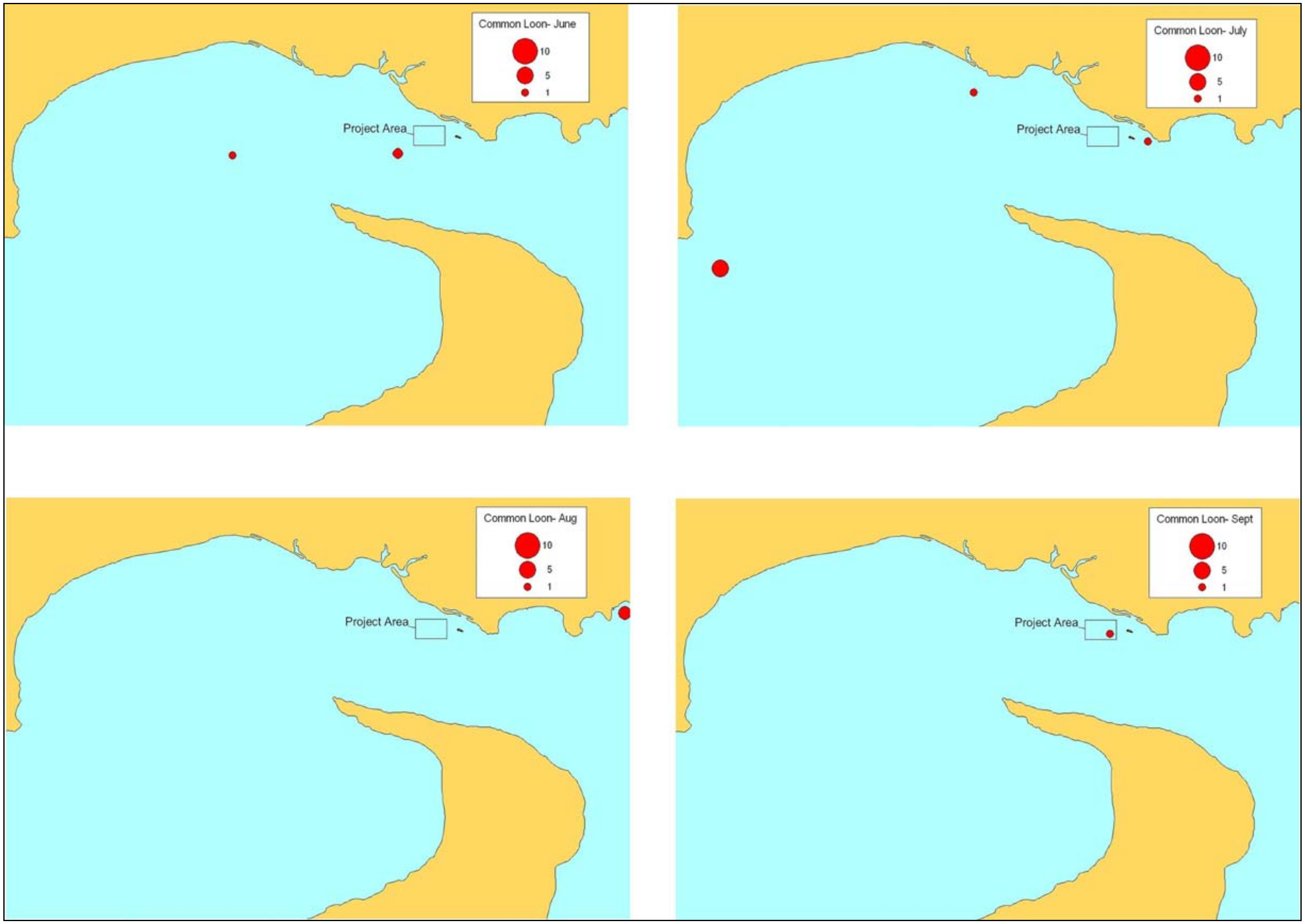

Figure 21. Distribution and abundance (individuals per 5-minute observation period) of Common Loon in Minas Basin, Minas Passage and Minas Channel, June to September 2009. Area shown is Crown Lease which contains berths for tidal device installation.

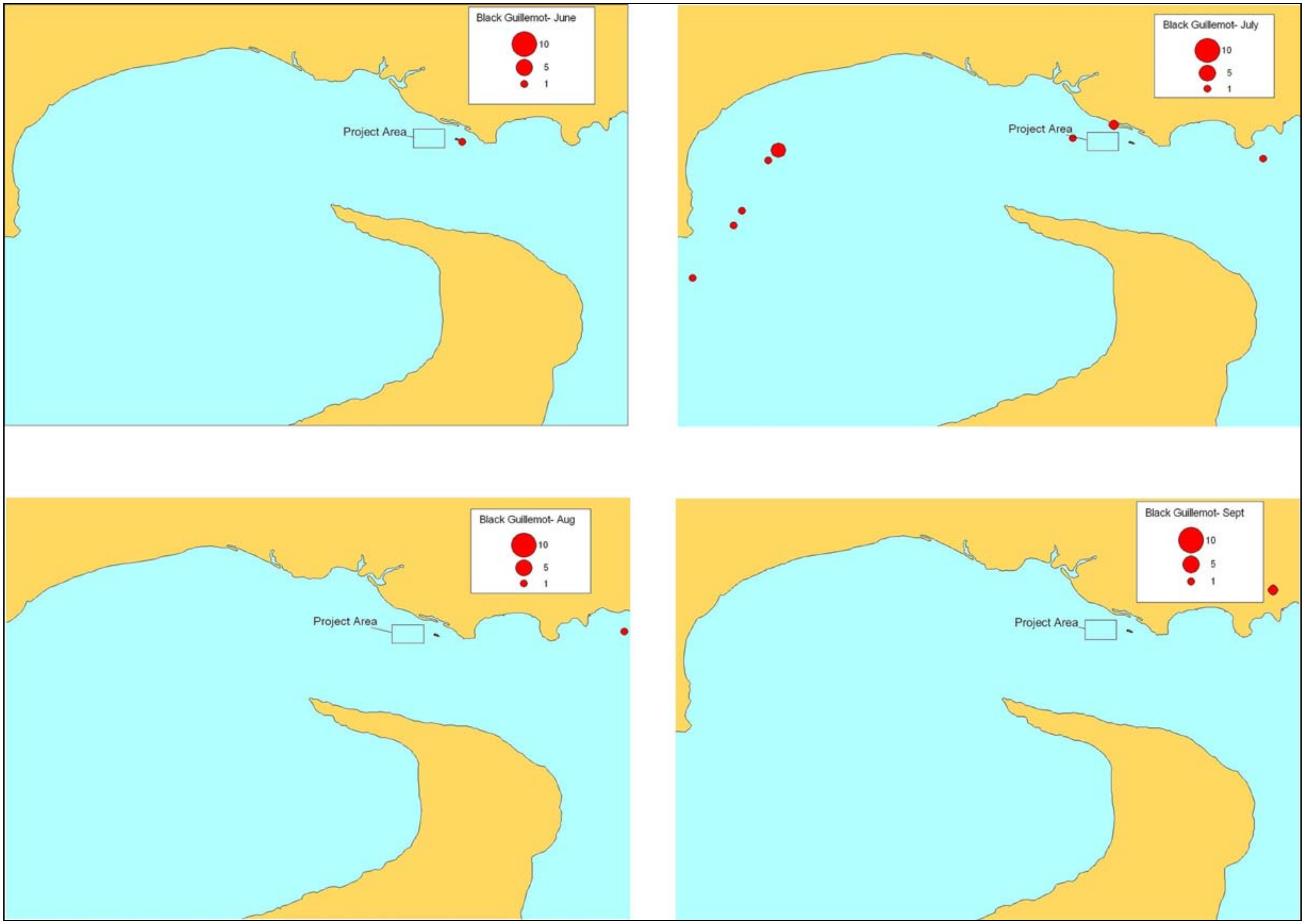

Figure 22. Distribution and abundance (individuals per 5-minute observation period) of Black Guillemot in Minas Basin, Minas Passage and Minas Channel, June to September 2009. Area shown is Crown Lease which contains berths for tidal device installation.

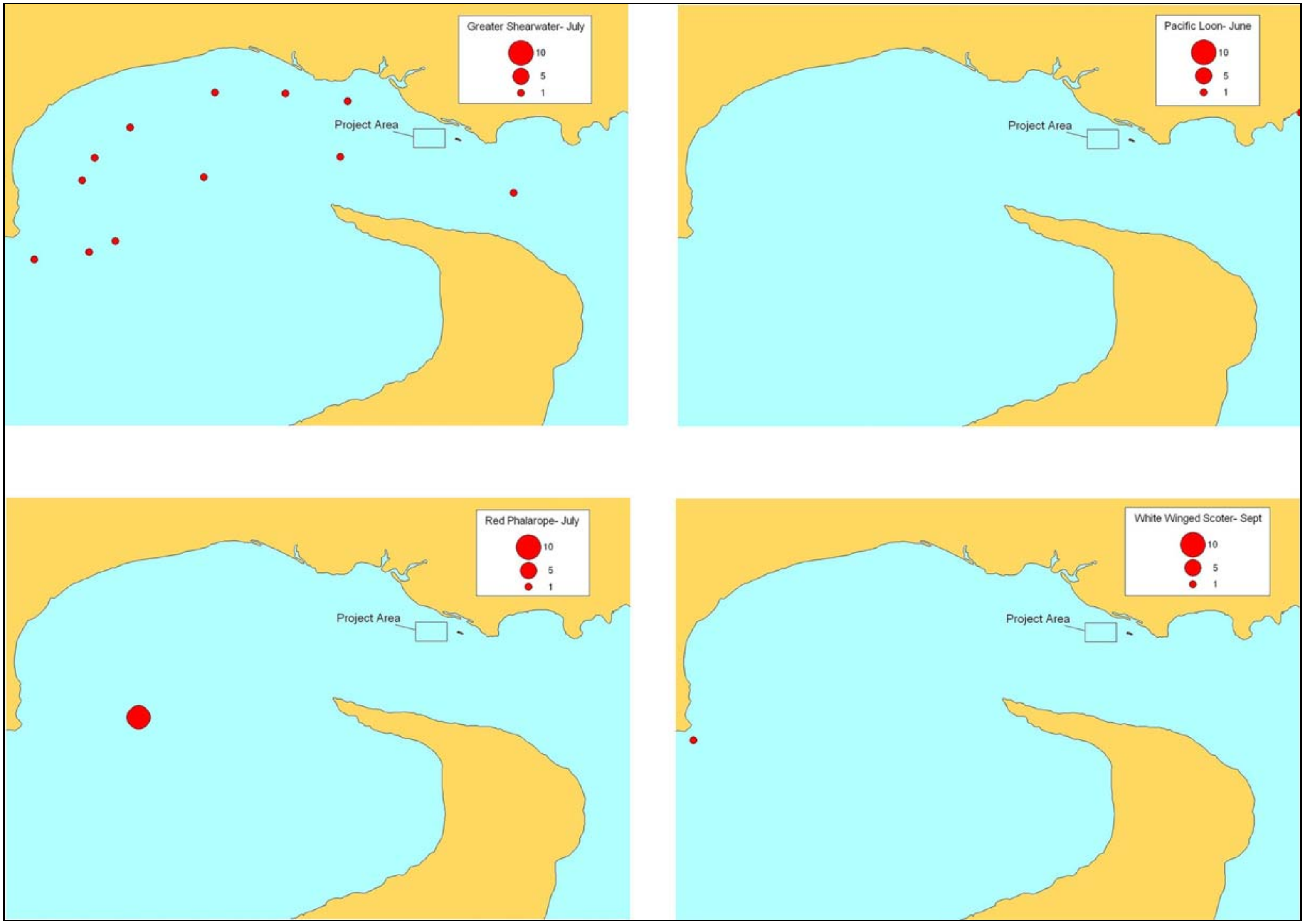

Figure 23. Distribution and abundance (individuals per 5-minute observation period) of seabird, waterfowl and shorebird species occurring in only one survey in 2009, Minas Basin, Minas Passage and Minas Channel, June to September 2009. Area shown is Crown Lease which contains berths for tidal device installation.

Great Black-Backed Gull

Great Black-Backed Gull was a common and ubiquitous resident of the area, occurring in all seasons, but notably least abundant in September (Figure 16) and more prevalent in Minas Passage. No differences between areas were statistically significant, but a significant seasonal difference occurred with a lower density per km^2 in Minas Basin in June than August ($p < 0.10$). Most individuals were adults with immatures and juveniles highest in September (June, 0%; July, 27.3 %, August, 11.0% and September, 100%) (Tables 4-7). The species is a common annual breeder in Atlantic Canada, which nests on islands and seacliffs along the Bay of Fundy, mainly feeding by scavenging along shores and at the water surface.

Ring-Billed Gull

Ring-Billed Gull was observed in August and September, restricted to Minas Passage and Minas Basin. Similar abundances were observed in Minas Passage in August and September, with no significant difference determined either in density per km^2 or abundance per kilometer (Tables 4-7, Figure 17). The absence of the species in Minas Channel resulted in a statistically significant difference between Minas Passage and Minas Channel in density per km^2 ($p< 0.05$). Most individuals were adults with immatures and juveniles occasionally important (July, 0%, August, 18.2 % and September, 60%) (Tables 4-7). Ring-Billed Gull is a common annual migrant and occasional summer resident, feeding typically at the water surface.

Common Eider

Common Eider were observed on all surveys (Figures 8 & 18), typically occurring in flocks in nearshore areas in the vicinity of the project site and near Black Rock. Abundance was similar on all surveys and no significant differences in abundance between months were observed in any of the areas in which the species occurred. The association of Eiders primarily with Minas Passage (the eiders observed in Minas Channel in September were just west of the Minas Passage boundary and only one sighting occurred in Minas Basin, Figure 18) was demonstrated by a significant difference in abundance per kilometer between Minas Passage and Minas Channel (significantly greater in both July and August ($p<0.1$) and overall ($p<0.05$)). Abundance per kilometer was highest in June, but density per km^2 was highest in August and September (the two measures of abundance do not agree because large eider flocks were sampled in the former and only smaller concentrations occurring near the boat were sampled in the latter). A varying proportion of immatures and juveniles occurred (June, 19.1%; July, 66.0 %, August, 0% and September, 87.9%) (Tables 4-7). Common Eider is a common breeder on islands and shoreline of Bay of Fundy. The species typically feeds on molluscs such as mussels, which it finds in intertidal and upper subtidal areas. Eider can dive to medium depths, occasionally deeper to reach the beds where their food is located.

Double-Crested Cormorant

Double-Crested Cormorant is a resident of the area, nesting in colonies in Minas Basin and Cape Split, and commonly seen on Black Rock, but was not seen much in the surveys, occurring in all months (Figure 19). Most individuals observed were adults and the only observations of immatures and juveniles were made in September (75% of total) (Tables 4-7). The species is a common annual breeder, which nests on islands and seacliffs along the Bay of Fundy, feeding by diving for fish to shallow to medium depths, occasionally deeper.

Northern Gannet

This species normally migrates through the area to colonies on the Gulf of St. Lawrence, but the Inner Bay of Fundy may support immatures and late migrants. Several were observed in the study area in July and August, with a cluster near the study area and in Minas Channel in August (Figure 20). Most of the observations were immatures or juveniles (July, 100%; August, 87.5%). Northern Gannet is a common annual migrant and summer resident. Feeding is by diving from great heights to medium and shallow depths to catch fish.

Common Loon

The species is a common coastal resident in the study area, occurring in all areas and months, with no particular areas of concentration. Common Loon forages by diving and swimming underwater to catch fish, diving mostly to medium depth, but occasional very deep dives are possible. Common Loon occurred sporadically throughout the study area in all areas and seasons (Figure 21). Most of the individuals observed were immatures (June, 66.7%; July, 100%; August, 66.7%; September, 100%). Common Loon is a common annual breeder on inland lakes and summer resident on the Bay of Fundy.

Black Guillemot

Black Guillemot were observed in all seasons and in all of the subdivisions of the study area, mostly in July (significantly higher, $p< 0.05$, than August in abundance per kilometre)(Figure 22). Most of the Black Guillemot observed were adults, with a single immature seen in September (50% of total observations). Black Guillemot is a common annual breeder on seacliffs and in coastal rocks along the Bay of Fundy. The species feeds on fish in dives of shallow to medium depth.

Occasional Species

Several species occurred in only one monthly survey, including Greater Shearwater, Pacific Loon, Red Phalarope (a shorebird), and White-Winged Scoter, a duck species. Greater Shearwater is an oceanic seabird, which commonly occurs in nearshore areas, particularly as immatures or diverted by storms into the Inner Bay of Fundy. The species occurred in the study area only in June (Figure 23), and 9 of 12 birds seen were juveniles (Table 4). Greater Shearwater is a common annual summer resident, which forages by swimming and diving underwater to shallow depths when catching fish. Individuals and occasional flocks were observed following the boats and alongside as a result of habituation, as they are often fed by fishermen. An immature Pacific loon, a West-Coast species, which had reached the area, was observed near Parrsboro in Minas Basin in the June survey. The species is a rare annual migrant or vagrant, which can occur in the area, and typically forages in very deep water, diving and swimming underwater to catch fish. A flock of immature Red Phalaropes, a common annual migrant shorebird species and surface feeder, was observed in Minas Channel in July. A single adult White-Winged Scoter was observed in September in Minas Channel near Cape Spencer. The species is a common migrant to the area, feeding on molluscs such as mussels, usually diving to medium depths and occasionally deeper.

3.3. Comparison with Previous Studies

Seabird densities in the study area are slightly lower than typical seabird densities in coastal and shelf areas in Nova Scotia waters (Fifield et al. unpubl manuscript) although peak densities can be comparable to those from adjacent areas of the Bay of Fundy. Densities[7] for total bird abundance (median value of birds per km^2) were zero in all areas and seasons in the study area except for July in both Minas Passage and Minas Channel when median abundances were 3.6 and 6.8 birds per km^2 respectively. In comparison, median densities on the Scotian Shelf-Gulf of Maine are 7.9 per km^2 in spring; 8.3 per km^2 in summer; 4.2 per km^2 in fall and 7.7 per km^2 in winter)(Fifield *et al* unpubl). Densities in 1˚ survey blocks which included the Minas Channel area in the Fifield *et al* study over the May-August period were 5.2 birds per km^2; at the mouth of Chignecto Bay over the same period were 2.5 birds per km^2; and in the outer Bay of Fundy off Digby, 9.8 birds per km^2. Another study (Lock et al. 1994) reported annual seabird densities off Digby to be 0.01-0.09 birds per km^2, which were comparable to typical densities at the study site, while densities on the New Brunswick side near Saint John were higher, at 10-13.9 birds per km^2.

Only Herring Gulls had median densities greater than zero (in Minas Passage in July, 3.0 birds per km^2), comparable to densities of 2.4 birds per km^2 for the block including Minas Channel for the May to August period in Fifield et al. and greater than at the mouth of Chignecto Bay or off Digby (0.8 and 0.1 birds per km^2) respectively.

Species observed in the present study includes all those observed in initial surveys for the tidal power demonstration project in July & October 2008 (Envirosphere Consultants Limited 2009) with the exception of a Northern Fulmar, and Wilson's Storm petrel, which were seen only in 2008. Effort in the earlier survey was lower (6.6 km of transects in July and 20.7 km in October 2008), and densities in the earlier study were comparable to those in the present stury, ranging from 0.2 birds per kilometer to 1.5 birds per kilometer.

3.4. Statistical Analysis of Area and Seasonal Differences in Seabird Abundance

The goals of the statistical analysis were to support the determination of general patterns in seabird distribution (by species, area and season); to determine the ability of the study design and level of sampling effort to demonstrate differences; and to evaluate various measures of seabird and waterfowl abundance, including overall and individual species abundances which could be used in environmental monitoring. Analyses were conducted of seabird abundance measures within months and annually and overall between areas; and within areas between months and annually. The lower level of sampling effort in Minas Basin (Figures 4-5) could have reduced the likelihood of detecting differences between Minas Basin and the other areas, as well as seasonal differences in that area. In addition, the June and September surveys had a lower level of effort than the other months, due to the lower sampling rate (one observation period every 15 minutes versus one every five minutes for July and August), which would have influenced the success of the analysis in detecting significant differences between June and September and other months. Only the dominant species in the area were considered in the analysis (e.g. Black Backed Gull, Herring Gull, Ring Billed Gull, Black Guillemot, and Common Eider as well as total bird density).

[7] Median values were used for comparison, since that is the measure used in seabird data summaries for the area.

3.4.1. Area Comparisons

Total Birds

The study design for the project was sufficient to allow detection of some differences between density per unit area and abundance per kilometer[8]. Density per unit area of total seabirds and waterfowl was significantly ($p<0.01$) lower in Minas Passage than Minas Channel in June; and significantly greater than Minas Channel ($p<0.05$) in August. No significant differences in total seabird density per km^2 between Minas Basin and Minas Passage were detected, although Minas Passage appears to have higher seabird density per km^2 in July and August, and for annual averages ($p<0.11$, 0.122 and 0.11 respectively). Additional effort in Minas Basin, as well as in all areas in June and September would have improved the likelihood of detecting differences if they occur.

Statistically significant differences in overall abundance of seabirds and waterfowl per kilometre between areas included: Minas Passage greater than Minas Channel (August, $p<0.01$); Minas Passage greater than Minas Basin (annual average, $p = 0.069$); and Minas Basin greater than Minas Channel (August, $p = 0.07$). Other comparisons with a probability of significance of ~ 0.1 were Minas Passage greater than Minas Basin (July, $p = 0.115$), Minas Passage greater than Minas Channel (annual, $p = 0.123$), and Minas Channel greater than Minas Basin (July, $p = 0.12$).

Great Black-Backed Gull

No statistically significant differences between areas were detected for any abundance measure of Great Black-Backed Gull between areas. The comparison of the June density per km^2 between Minas Basin, which appears higher, and Minas Passage had a probability of 0.138; and abundance in Minas Channel appeared to be higher than Minas Passage in June ($p = 0.113$) but these differences are not statistically significant. Abundance per kilometer of Great Black-Backed Gull in June also appeared higher in Minas Channel than in Minas Passage though the probability reflecting the magnitude of the difference ($p = 0.139$) was not statistically significant. Some individual differences between months were observed in each of the geographic subdivisions of the study area, and are outlined in Section 3.3.2.

Herring Gull

The analysis detected several differences in Herring Gull abundance. The difference in Herring Gull abundance per km^2 between areas in June was statistically significant (the species was not observed in Minas Basin or Minas Passage at that time so this is in effect a presence-absence test); Herring Gull density per km^2 in Minas Channel was higher in June than in both other areas ($p<0.05$ and $p<0.01$ for the difference with Minas Basin and Minas Passage respectively). In July, when Herring Gulls were most abundant overall in the area, the difference between abundance per km^2 in Minas Passage and Minas Basin (Minas Passage higher) was significant at the $p<0.1$ level; however an apparent greater density in Minas Passage than in Minas Channel in June was not statistically significant ($p = 0.139$).

Herring Gull abundance per kilometer in Minas Channel was similarly higher in June than in both other areas ($p<0.05$ and $p<0.01$ for the difference with Minas Basin and Minas Passage respectively). In July, the difference between Minas Passage and Minas Basin (Minas Passage higher) was significant at the $p<0.05$ level. Apparent differences in abundance per km^2 between Minas Channel and other areas in August (Minas Channel lowest) were not statistically significant (Minas Passage, $p = 0.134$ and Minas

[8] The 'per unit area' estimate is always referred to in this discussion as 'density per unit area' and the 'per kilometre' estimate as 'abundance per kilometre' for clarity to distinguish them.

Basin, $p = 0.11$). Some individual differences between months were observed in each of the geographic subdivisions of the study area, and are outlined in Section 3.3.2.

Common Eider

The analysis detected differences in abundance per kilometre for Common Eider, with Minas Passage significantly greater than Minas Channel in both July and August ($p<0.1$) and overall ($p<0.05$). For overall density per km^2 for the study as a whole, the absence of eiders in Minas Channel in all months except August compared with other areas was not significant ($p = .14$ and $p = 0.135$ respectively). Individual differences between months were observed in each of the geographic subdivisions of the study area, and are outlined in Section 3.3.2.

Ring-Billed Gull and Black Guillemot

Ring-Billed Gull annual average density per km^2 was significantly greater in Minas Passage compared to Minas Channel ($p < 0.05$) (reflecting that this species was not seen in Minas Channel), but the difference with Minas Basin was not significant (e.g. $p = 0.106$). The occurrence of Ring-Billed Gull in Minas Passage but not in Minas Channel in August was statistically significant ($p < 0.1$). The occurrence of Ring-Billed Gull in Minas Basin and Minas Passage, but not in Minas Channel was also highlighted in statistically significant comparisons for abundance per kilometer ($p<0.05$) with Minas Channel for both Minas Basin (August) and Minas Passage (annual average). No significant differences were detected between areas for Black Guillemot. The species was only occasionally encountered, and occurred in all areas and months, particularly in Minas Channel in July, but the pattern was not detected by the analysis at this level [an area difference was detected in the two-way analysis of variance, Section 3.3.3]. Some additional individual differences between months were observed in each of the geographic subdivisions of the study area, and are outlined in Section 3.3.2 below.

3.4.2. Seasonal Comparisons

Minas Basin

Several statistically significant differences in abundance for total birds and for the abundance of individual dominant species were detected in Minas Basin. For overall bird abundance, the difference between June and August in birds per kilometer (August abundance higher) was statistically significant ($p < 0.10$)[9]. None of the species showed significant ($p<0.05$) differences in either density per km^2 or abundance per kilometer between months overall; however the difference between months for Black Guillemot were significant at the $p <0.10$ level. Black Guillemot also showed differences between August and September in density per unit area (September higher) ($p< 0.10$). Differences between specific months for several other dominant species included: Great Black-backed Gull (higher density per km^2 in June than August, $p < 0.10$); and Herring Gull (higher in both density per km^2 and abundance per kilometer in August and September than June, $p < 0.10$, and higher in abundance per kilometer in August than June ($p < 0.05$). Several differences, which had probabilities, which were slightly above statistical significance levels, may possibly be detected in future by additional sampling effort. These included: density per km^2 between months overall for Great Black-Backed Gull (sightings in July & August, $p<0.151$); total numbers per kilometer between months overall for Herring Gull (high number of sightings in August and lower numbers in July and September but not in June, $p = 0.147$) and for density per km^2 between August and June (June higher, $p = 0.166$); Ring-Billed Gull abundance per kilometre between months overall (highest in August but absent at other times, $p<0.178$), and between August and July

[9] Comparisons included: between months overall and between pairs of months individually.

(August higher, $p = 0.124$); and Common Eider for density per km^2 and abundance per kilometer between July and August (higher in July, $p = 0.178$).

Minas Passage

Various statistically significant differences in abundance measures for total birds and for the abundance of individual dominant species, both between months overall and between specific months, were also demonstrated in Minas Passage. Significant differences were shown between months overall in total seabird and waterfowl density per km^2 ($p<0.001$, density was high in July, low in June and medium in August and September). Differences in abundance per kilometer between months overall (highest in June and September), however, were not statistically significant. A reanalysis of differences between months overall without Common Eiders (which greatly influence the abundance per kilometer and might have affected the statistical comparison) also did not detect significant differences in abundance per kilometer although the July and August abundances were higher than at other times (similar to the observation for density per unit area, although not at a significant level, $p=0.124$). Comparisons by month of total bird density per unit area showed highly significant differences between June and the July and August measures (July and August higher, $p < 0.001$ and $p<0.01$ respectively), and between July and the August and September measures (July higher, $p < 0.05$ for both comparisons). Similar to the comparison between months overall, the estimate of total bird abundance per kilometer was only marginally significant for the July-August comparison (July higher, $p < 0.1$).

Statistically significant differences in densities per km^2 and abundance per kilometer of individual dominant species, specifically Herring Gull, Common Eider and Ring-Billed Gull, occurred between months overall and between specific months. Herring Gull abundance, both density per km^2, and abundance per kilometer, were significantly different between months overall ($p < 0.001$), highest in July and August, and were significantly higher in Minas Passage in July than in August, ($p< 0.01$). Comparison of Herring Gull density per km^2 and abundance per kilometer between specific months showed highly significant differences between both measures in June (which was lowest) compared with those in July and August ($p < 0.001$ and $p < 0.01$ respectively); between density per unit area for July (higher) compared with August and September ($p<0.01$ and $0<0.001$ respectively); for abundance per kilometer in July (higher) compared with September ($p < 0.001$); and for abundance per kilometer in August (higher) compared with September ($p < 0.1$). Common Eider density per km^2 was higher in September than in July, but not significantly ($p = 0.11$). Occurrences of Ring-Billed Gull in Minas Passage in August and September but not at other times created a seasonal difference detected by the analysis both in density per km^2 and abundance per kilometer overall, but at a low level of significance ($p < 0.089$ and 0.07 respectively). Similarly the comparisons by month for both abundance measures for Ring-Billed Gull showed a low level of significance for comparisons between August and September and June (only the September-June comparison for density per km^2 was significant ($p<0.10$)); and for the comparisons between August and September and July (for density per unit area, $p<0.01$ and $p<0.05$, respectively, and for abundance per kilometer, $p<0.05$ for both comparisons). These results show for Ring-Billed Gull that the reduced sampling intensity in June in Minas Passage reduced the ability of the analysis to detect real differences such as the presence or absence of the species; however, where effort was higher, as in July, the difference could be detected.

Minas Channel

In Minas Channel, differences in abundance, which were statistically significant, occurred between months overall and for specific months for total birds and for the abundance of individual dominant species. Significant differences were observed between months overall, reflecting a relatively higher abundance in June and July and lower in August-September ($p<0.001$). Abundance per kilometer also showed statistically significant differences between months ($p< 0.01$), with highest abundance in July and

September. Overall density per km^2 was higher in June than in August ($p<0.05$), and higher in July than compared with either August or September ($p<0.001$ and $P<0.05$ respectively). Overall abundance per kilometer was higher in July than in June and August ($p<0.059$ and $p<0.05$ respectively). Although overall bird density per km^2 was higher in July than in September, abundance per kilometer was higher in September than in July ($p<0.05$). Herring Gull and Great Black-Backed Gull were widespread in Minas Channel, and no statistically significant differences with month overall were detected, although abundances of both appear to be lower in June and September (probabilities of a seasonal difference were $p = 0.151$ for density per km^2 of Great Black-Backed Gull and $p = 0.147$ for abundance per kilometer of Herring Gull). Of the two species, only Herring Gull had significant differences in comparisons of specific months, with the density per km^2 significantly lower in June and July than in August ($p<0.05$ and $p<0.01$ respectively); and for abundance per kilometer, August was lower than July ($p<0.10$). The density per km^2 of Black Guillemot, which was high in Minas Channel in July accounted for a significant statistical difference between months overall at the $p<0.1$ level, and for a significant difference in abundance per kilometer between July and August (lower in August, $p<0.05$). Both Common Eider and Ring-Billed Gull abundance per kilometer in Minas Channel were higher in September than in July and August ($p<0.10$).

3.4.3. Area x Season Comparisons

The two-way analysis of variance supported the general conclusions of the analysis of seasonal and area differences separately, showing that seasonal patterns in the data were generally stronger than those between areas. Strong seasonal differences were demonstrated for total bird abundance per km^2 ($p<0.001$); Herring Gull abundance per km^2 ($p<0.001$) and per kilometer ($p<0.01$); Black Guillemot abundance per km^2 ($p<0.05$); and Ring-Billed Gull abundance per kilometer ($p<0.01$). Strong area effects were only observed for Ring-Billed Gull abundance per km^2 ($p<0.01$), while less significant area effects were observed for total bird abundance per kilometer ($p<0.1$) and Black Guillemot abundance per km^2 ($p<0.1$). Significant interactions between season and area in the analysis were shown for: total bird abundance per km^2 ($p<0.05$); Herring Gull abundance per km^2 and per kilometer ($p<0.05$ and $p<0.1$ respectively); Black Guillemot abundance per km^2 ($p<0.01$); and Ring-Billed Gull abundance per km^2 ($p<0.1$). Notably neither Common Eider or Great Black-Backed Gull demonstrated significant seasonal or area differences in this analysis.

3.4.4. Statistical Analysis Summary

The sampling design was sufficient to detect various patterns in abundance both seasonal and in terms of sub-areas within the overall study area. More seasonal differences in both density per km^2 and abundance per kilometer were determined to be statistically significant than differences between areas (Table 8a & b). In terms of seasonal differences, Minas Basin had the least number which were statistically significant, possibly due to the smaller sampling effort expended there. The majority of the significant differences were accounted for by total bird abundance, as well as individual abundances of Herring Gull, Ring-Billed Gull and Black Guillemot. Common Eider demonstrated no significant seasonal differences for density per km^2 (the species was not usually captured in the quantitative density sampling protocol) but showed some significant seasonal differences in the estimates of abundance per kilometer, in which Common Eider flocks were included. Great Black-Backed Gull notably had few significant differences. Seasonal differences are expected in bird populations and these results appear to demonstrate this tendency.

Table 8a. Summary of significant differences detected by statistical analysis between seasons within areas.

Seasonal Differences overall and by area																
	Density per Unit Area								Abundance per Kilometre							
	Minas Basin		Minas Passage		Minas Channel		Whole Area		Minas Basin		Minas Passage		Minas Channel		Whole Area	
Comparison	o	i	o	i	o	i	o	i	o	i	o	i	o	i	o	i
Total Birds	--	--	X	X	X	X	X	X	X	X	P	P	X	X	X	X
HEGU	--	X	X	X	X	X	X	X	--	X	X	X	--	X	X	X
GBBH	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--
RBGU	--	--	X	X	--	--	X	X	--	--	X	X	X	X	X	X
COEI	--	--	--	P	--	--	--	--	--	--	--	P	X	X	--	X
BLGU	X	X	--	--	X	--	X	X	--	--	--	--	X	X	X	X
HEGU = Herring Gull; BGGH = Great Black-Backed Gull; RBGU = Ring-Billed Gull; COEI = Common Eider; BLGU = Black Guillemot. Comparisons: o = between months overall for area shown; i = individual month comparisons for area shown. Statistical significance: -- = no significance; P = probability ~ 0.1; X = probability between 0.05 and 0.10; X = significance level < 0.05.																

Table 8b. Summary of significant differences in statistical analysis between areas within seasons.																				
Area Differences overall and by Season																				
	Density per Unit Area										Abundance per Kilometre									
	June		July		August		Sept.		Annual		June		July		August		Sept.		Annual	
Comparison	o	i	o	i	o	i	o	i	o	i	o	i	o	i	o	i	o	i	o	i
Total Birds	X	X	--	P	X	X	--	--	--	--	--	--	--	P	--	--	--	--	--	--
HEGU	X	X	--	X	--	--	--	--	--	--	--	X	P	X	--	P	--	--	--	--
GBBH	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
RBGU	--	--	--	--	X	X	--	--	X	X	--	--	--	--	X	X	--	--	X	X
COEI	--	--	X	X	--	--	--	--	--	P	--	--	--	X	X	X	--	--	X	X
BLGU	--	--	--	--	--	--	P	--	--	--	--	--	--	--	--	--	P	--	--	--
HEGU = Herring Gull; BGGH = Great Black-Backed Gull; RBGU = Ring-Billed Gull; COEI = Common Eider; BLGU = Black Guillemot. Comparisons: o = between months overall for area shown; i = individual month comparisons for area shown. Statistical significance: -- = no significance; P = probability ~ 0.1; X = probability between 0.05 and 0.10; X = significance level < 0.05.																				

In contrast to seasonal differences, relatively few significant differences in seabird and waterfowl densities between areas were observed (Table 8b). For seabird density per km^2, total birds, Herring Gull and Ring-Billed Gull showed the most significant differences between areas, with some noted for Common Eider. Differences between area for seabird and waterfowl abundance per kilometer were most prominent for Ring-Billed Gull and Common Eider, and secondarily for Herring Gull, but not for the other species.

3.4.5. Monitoring Considerations

Detection of Impacts

Environmental monitoring associated with a project is important primarily to verify the impact hypotheses of an environmental assessment, but is also important to detect situations, which are not expected, based on available information an baseline sampling. As well, it is important that environmental monitoring programs be adaptive to changes and changing needs (see Lindenmayer and Likens 2009), such as the events which were not foreseen (e.g. a new species which becomes dominant in the area) or changes in sampling effort when it is determined that more sampling is required to improve statistical power.

In terms of environmental monitoring of seabirds at the Fundy Tidal Demonstration site, the present study provides information on occurrence and species composition of marine mammals in the study area, as well as empirical information which demonstrates that various types of differences in seabird and waterfowl distributions, both seasonally and by area, can be detected by a simple study design. In particular it shows the importance of sampling effort in determining significant differences (e.g. low effort and few significant differences detected in Minas Basin); and the importance of focusing on widely occurring and common species, as well as overall bird abundance in determining significant differences. In terms of sampling effort, a reduced frequency of sampling in June and September surveys, probably limited the ability of the survey to detect differences. Highly clumped species, such as Common Eider, were less likely to have significant differences demonstrated because of their statistical distributions; however the differences may be present and detectable by additional sampling effort. The present study was designed without knowledge of bird distributions in the area and their statistical properties, and was intended to collect a maximum number of observations in a tidal cycle over what was considered to be the important (ecologically) summer period. Other times of year are important for seabirds in the Bay of Fundy (for example the Fall is important for migrants and overwintering species). The abundance of birds demonstrated by this project, and the pattern of increased abundance of dominant species in the July-August period, suggests that the survey adequately covers the critical period for the dominant seabirds in the area, which is important in a monitoring program. Further, in addition to providing information on species composition of the seabird community in the area, the survey has provided statistical information, which can assist in further monitoring.

In terms of possible impact hypotheses for the project on seabirds and waterfowl, the present study design with additional effort in Minas Basin, and as well as in June and September could probably detect changes in abundance of the species from year to year or presence-absence; and also differences in response related to effects concentrated in a particular area (e.g. localized effect). For example, the present analysis detected a significant difference in the seasonal occurrence of Black Guillemot (a relatively uncommon species) in Minas Basin ($p<0.1$), which occurred in only two of the surveys. In Minas Passage, which had moderate sampling effort, seasonal differences, which were statistically significant, were detected for overall seabird density per unit area, and for both abundance estimators for Herring Gull and Ring-Billed Gull. In Minas Channel, which had a sampling effort similar to that for Minas Passage, the analysis detected the occurrence of a species in one season (density per km^2 of Black Guillemot also showed a significant seasonal variation ($p<0.1$)) as well as significant seasonal differences for overall seabird density per km^2 ($p<0.01$), and for abundance per kilometer ($p<0.1$).

Changes to Survey Design

Although the present design yielded useful information and also was efficient in utilization of vessel and observer time, there are several points, some noted above, in which improvements can be made. The smaller observer effort in Minas Basin compared to the other areas interferes with statistical determination of differences between areas, but also does not provide as complete and accurate a picture of species composition and abundance. Minas Basin is important intrinsically and as a downstream/upstream control for the study site. More sampling could be done in Minas Basin between Cape Sharp and Parrsboro, for example by including a sampling grid between Cape Sharp and Parrsboro, similar to that used in the project area. The sampling pattern in the Project area (Crown Lease area) of Minas Passage covers a much larger area than the project and consequently a relatively small number of observations was obtained within the Project area and the locations were essentially random. The grid could be adjusted so that a higher density of sampling, and repeated stations, takes place in the project area.

The observation intensity should probably be set for all surveys to be as often as possible (i.e. observations every five minutes if possible). Acknowledging this is a demanding requirement for a single observer, it could be carried out with an assistant to the observer, to track supporting information etc. from the navigation system.

4. CONCLUSIONS AND RECOMMENDATIONS

The study found low densities of seabirds and waterfowl in Minas Basin, Minas Passage and Minas Channel, which confirms the understanding that the area is not particularly important for them. Deep diving species, including Common Loon, Northern Gannet, and Black Guillemot, which the main group potentially impacted by contact with turbines, were not common, and the likelihood of interactions with seabed installations would be relatively low. Densities are expected to be higher in the spring and fall migratory periods (which were not sampled in the present survey) but probably will also be low in comparison to other areas of the Bay of Fundy and other Nova Scotia coastal waters, and therefore not likely to lead to significant interactions with and impacts from the turbine installations.

The present study design with modifications to: 1) include more uniform sampling effort in all sub-areas; 2) to have a uniform high sampling frequency in all surveys (i.e. continuous observations, every five minutes); and 3) to be more targeted and repeatable at the project site, would likely be sufficient to detect differences included in the impact hypotheses of the environmental monitoring program for the project. If at all possible, the highest observation frequency should be instituted in subsequent surveys. It is possible for a single observer to carry out observations at this level of effort, taking breaks at non-critical periods, and that is recommended.

The time period targeted for the surveys successfully captured the peak period of seabird abundance for the area and would provide the best opportunity for making statistical comparisons in addressing impact hypothesis in future monitoring programs. The survey period does not cover spring and fall migratory movements of seabirds and waterfowl through the Bay of Fundy, however, and it has been pointed out by bird observers that the peak period for utilization of the area by loons and gannets, is in the April-May, and October-November period. Both species are diving birds (a group having the highest likelihood of being impacted by tidal turbines). Consequently, to ensure a complete representation of bird distribution patterns at the site, particularly diving birds, it may be advantageous to conduct a survey in each of these time periods. Winter and early spring are unlikely to be important for birds at the site.

The observation process could be improved by including an assistant with the seabird observer to record position and course information, or alternately including a second observer, although the latter would be a complication in the analysis. Additional sampling effort should be placed in Minas Basin to ensure adequate data to allow comparisons and detect differences. This could be accomplished by adding survey lines in this area.

Useful impact hypotheses could be developed around total seabird density per km^2 and abundance per kilometer, as well as for several dominant species including Herring Gull, Ring-Billed Gull, Common Eider and Black Guillemot. Some of the other species which were not assessed statistically because of their low numbers or occurrence oval (e.g. Double-Crested Cormorant and Greater Shearwater) could be used in year-to-year comparisons to assess impacts.

A moderate number of marine mammals including harbour porpoise (most common), white-sided dolphin, harbour seal, and whales in the study area were observed in the survey. Additional survey effort (i.e. additional cruises) would be required to obtain better observations of the less common groups—whales, dolphins and Harbour Seal, although the possibly of finding low numbers may not warrant the additional effort. Routine surveys similar to the present one in future monitoring programs will provide additional data on these species.

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APPENDIX A– Frequency Distributions of Density of Dominant Seabird and Waterfowl Species

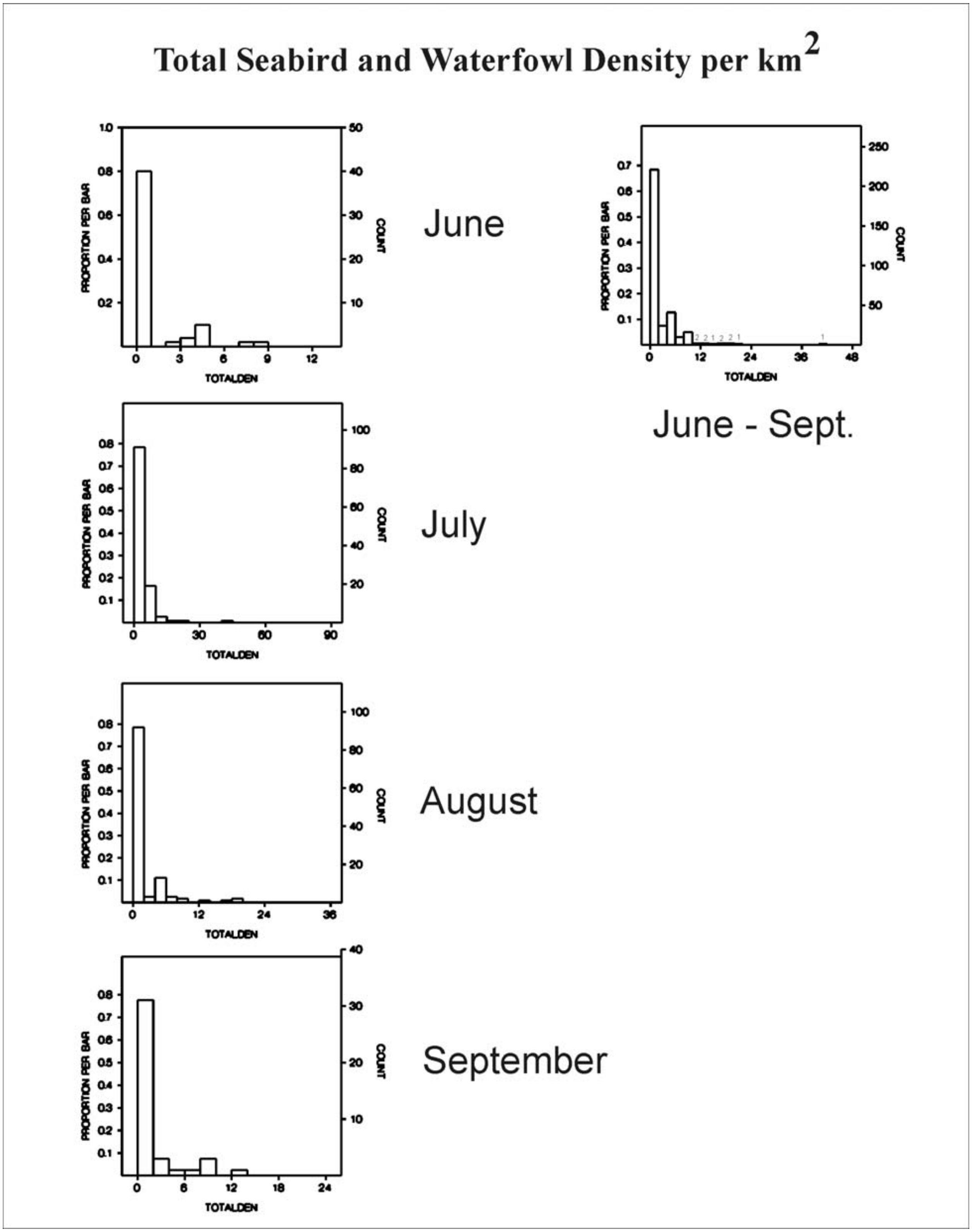

Figure 1. Monthly and overall frequency distribution of total seabird and waterfowl density per km², determined from sightings within 300 m of survey vessel, June to September 2009.

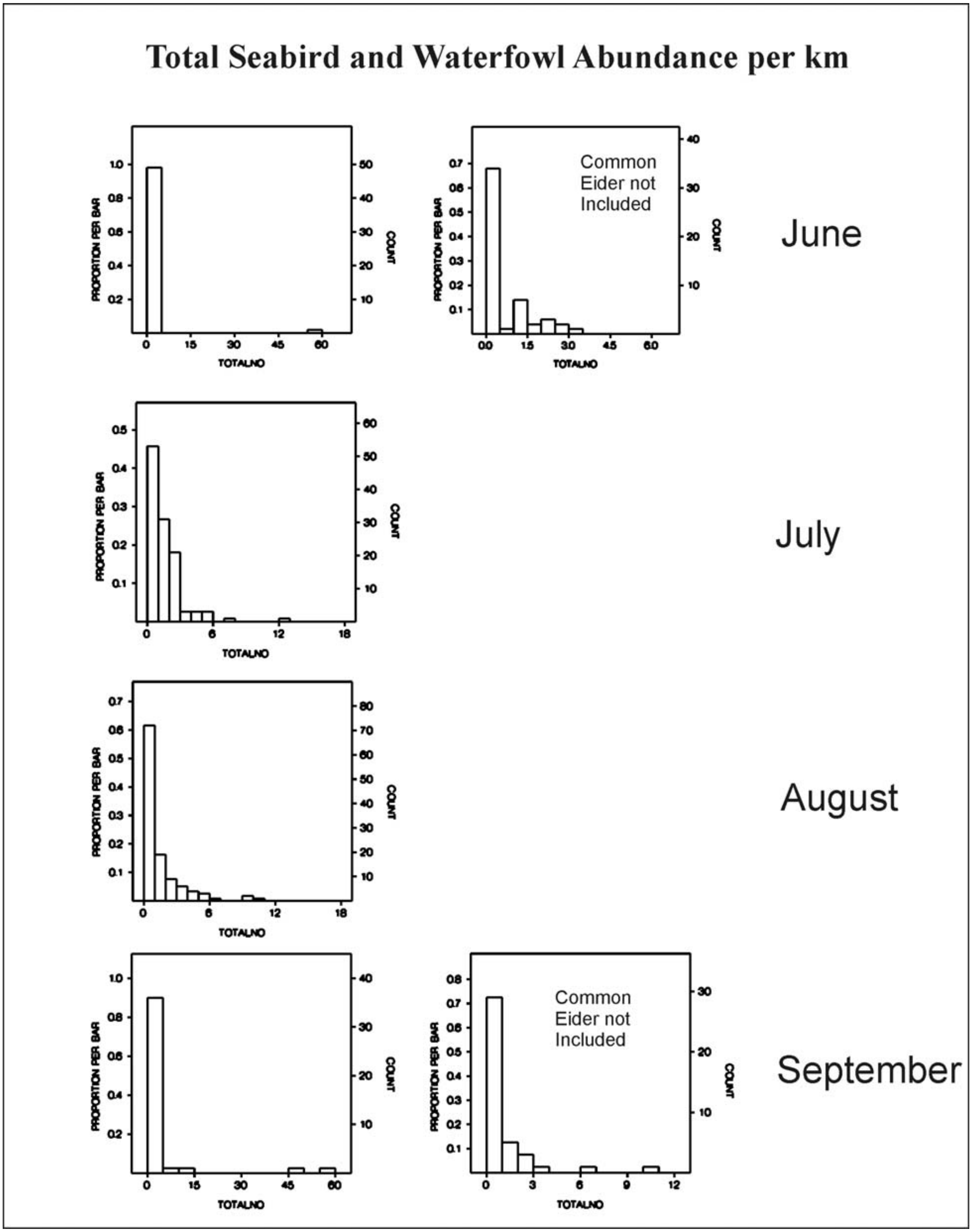

Figure 2. Monthly frequency distribution of total seabird and waterfowl abundance per kilometre, including birds observed further than 300 m from survey vessel, June to September 2009.

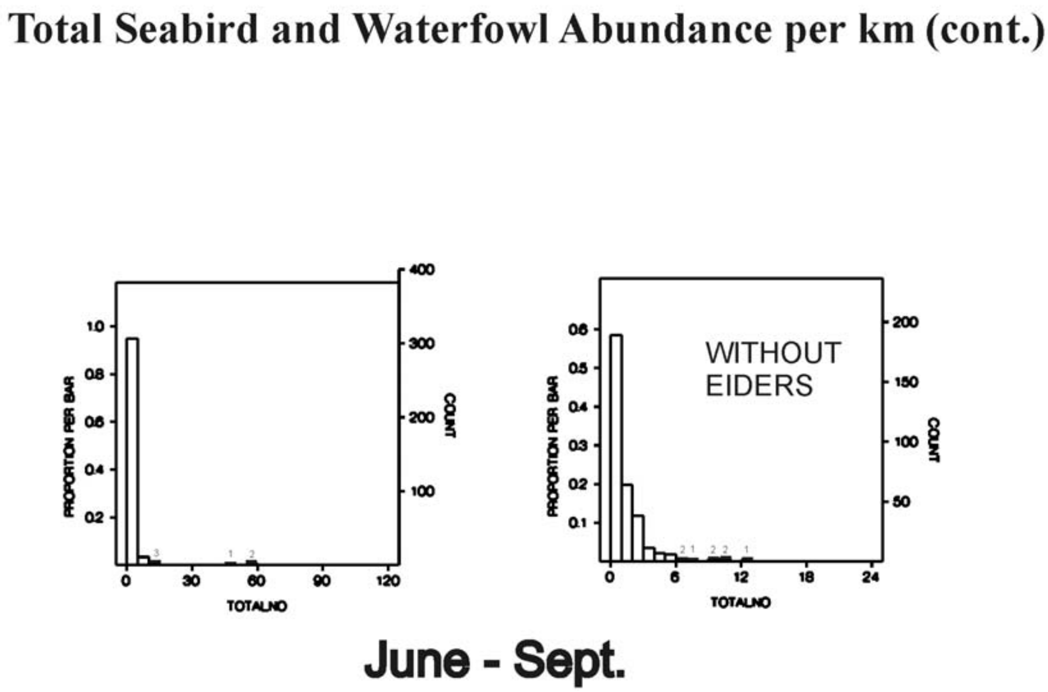

Figure 2 (con't). Monthly and overall frequency distribution of total seabird and waterfowl abundance per kilometre, including birds observed further than 300 m from survey vessel, June to September 2009.

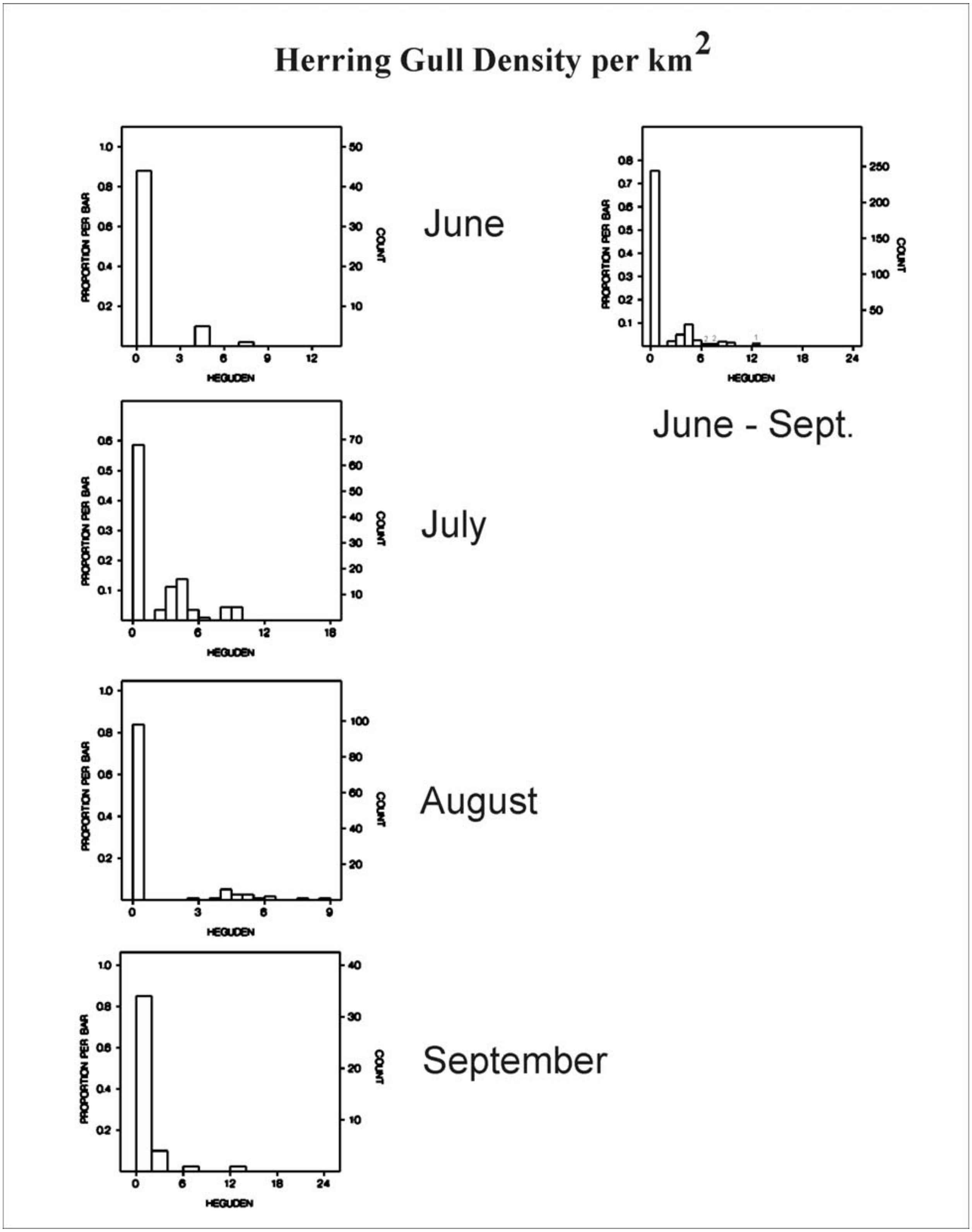

Figure 3. Monthly and overall frequency distribution of Herring Gull density per km^2, determined from sightings within 300 m of survey vessel, June to September 2009.

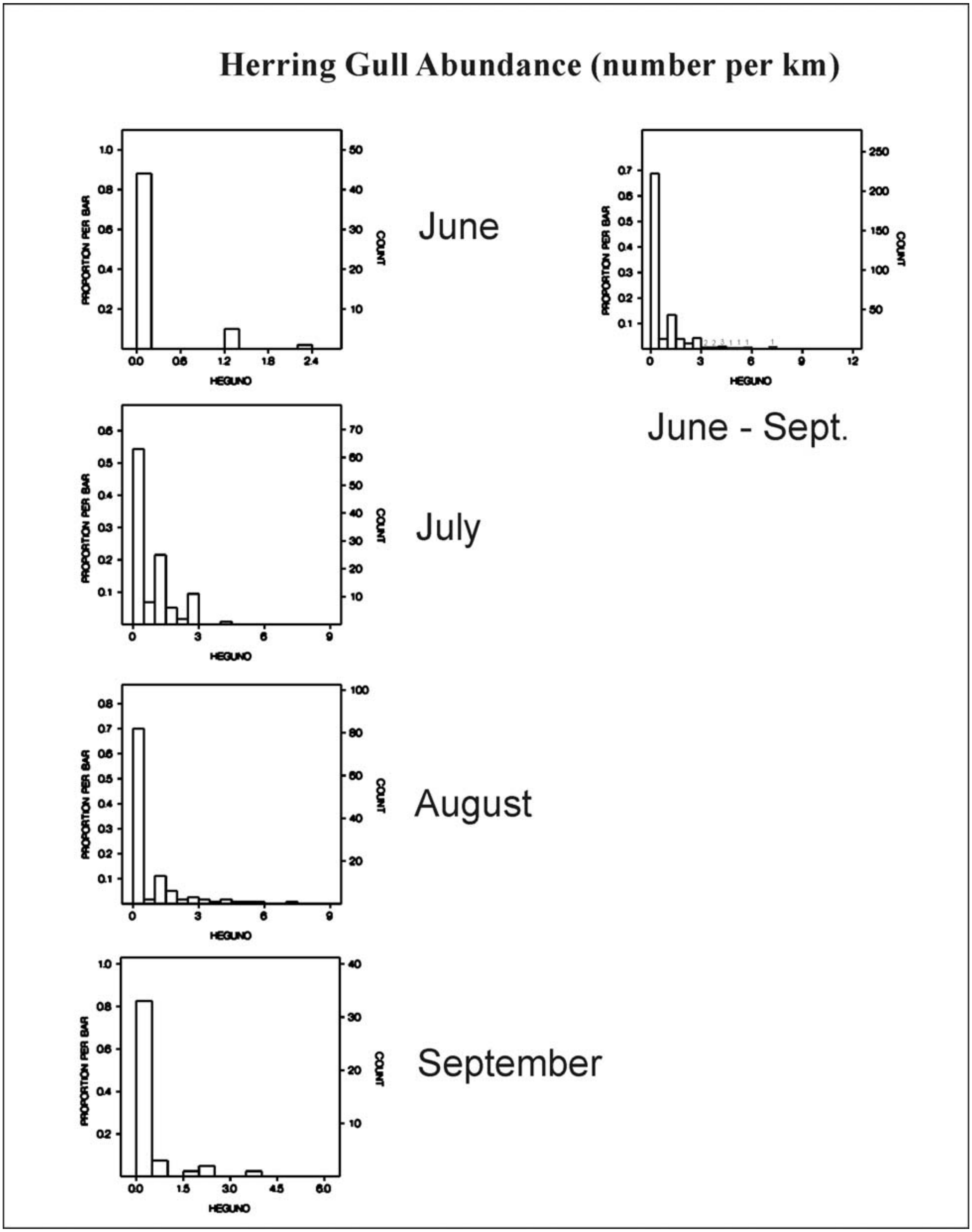

Figure 4. Monthly and overall frequency distribution of Herring Gull abundance per kilometre, including birds observed further than 300 m from survey vessel, June to September 2009.

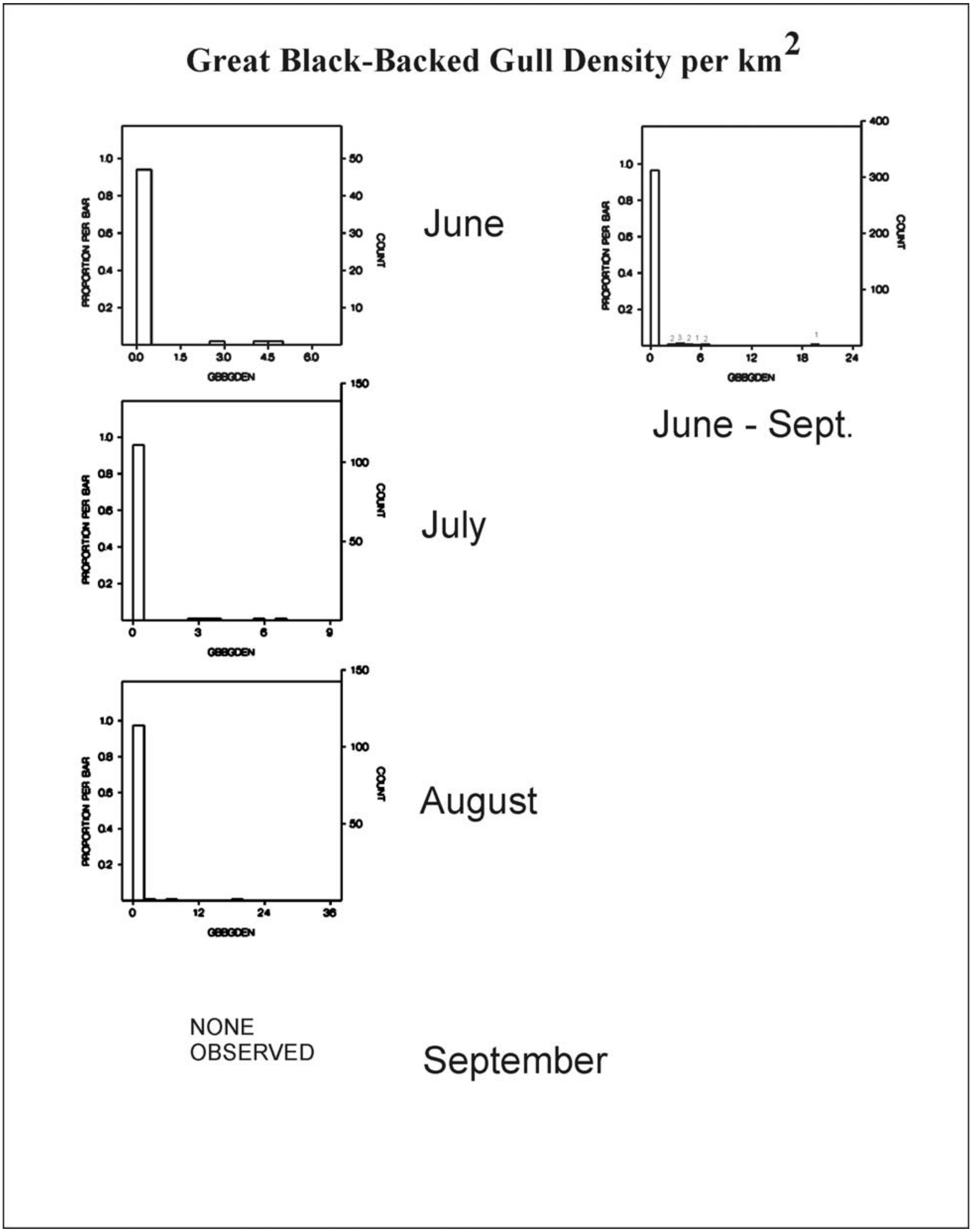

Figure 5. Monthly and overall frequency distribution of Great Black-backed Gull density per km^2, determined from sightings within 300 m of survey vessel, June to September 2009.

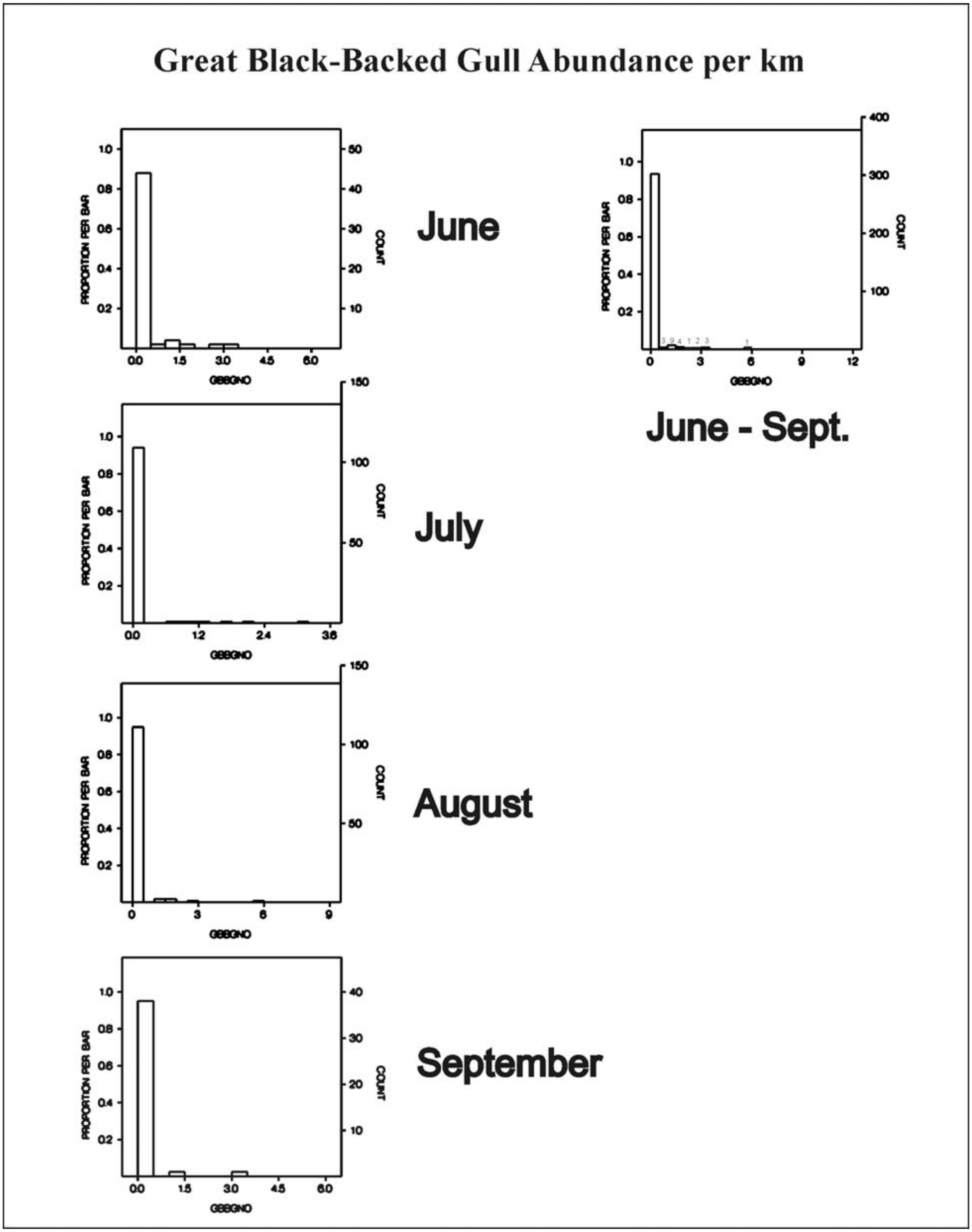

Figure 6. Monthly and overall frequency distribution of Great Black-Backed Gull abundance per kilometre, including birds observed further than 300 m from survey vessel, June to September 2009.

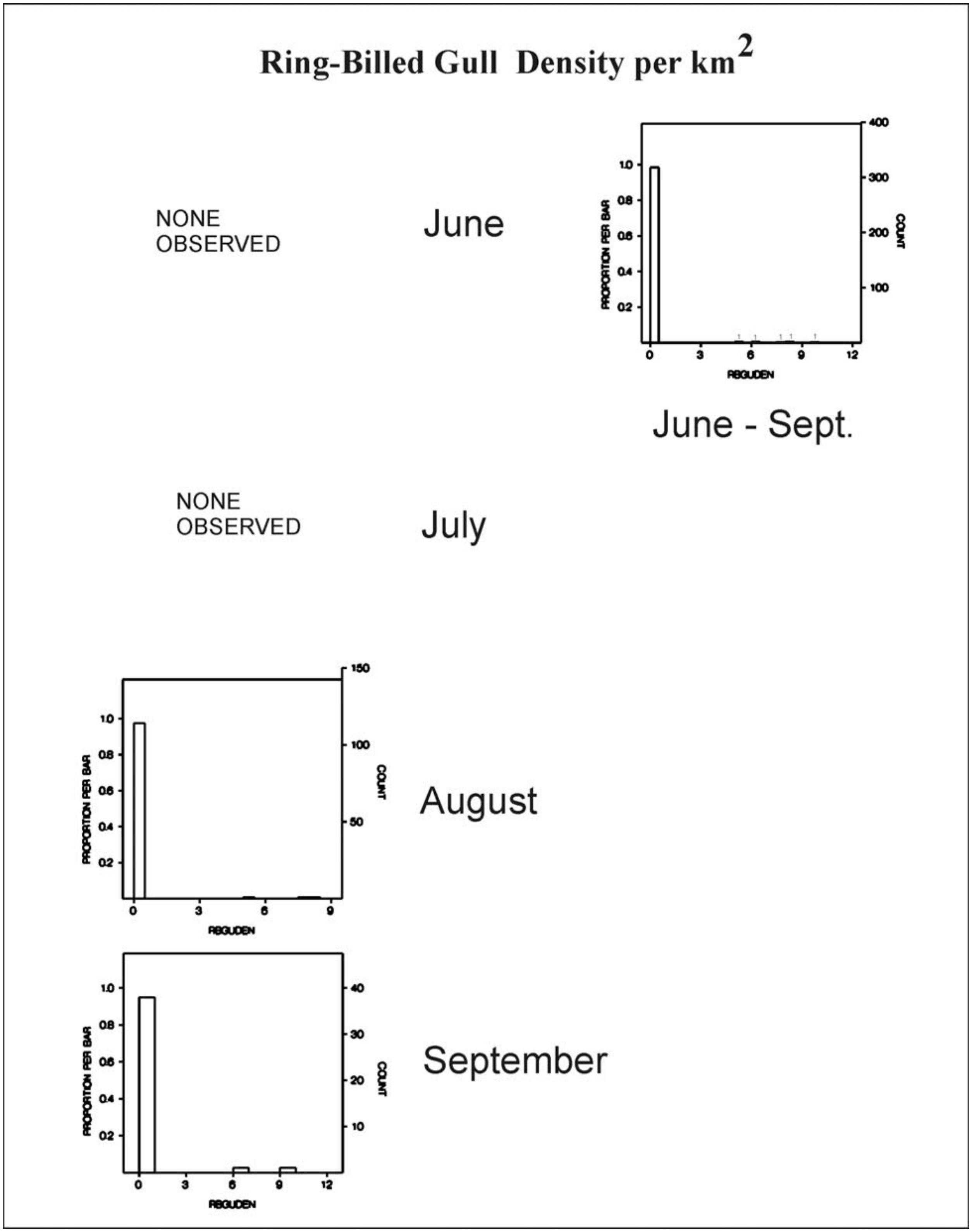

Figure 7. Monthly and overall frequency distribution of Ring-Billed Gull density per km^2, determined from sightings within 300 m of survey vessel, June to September 2009.

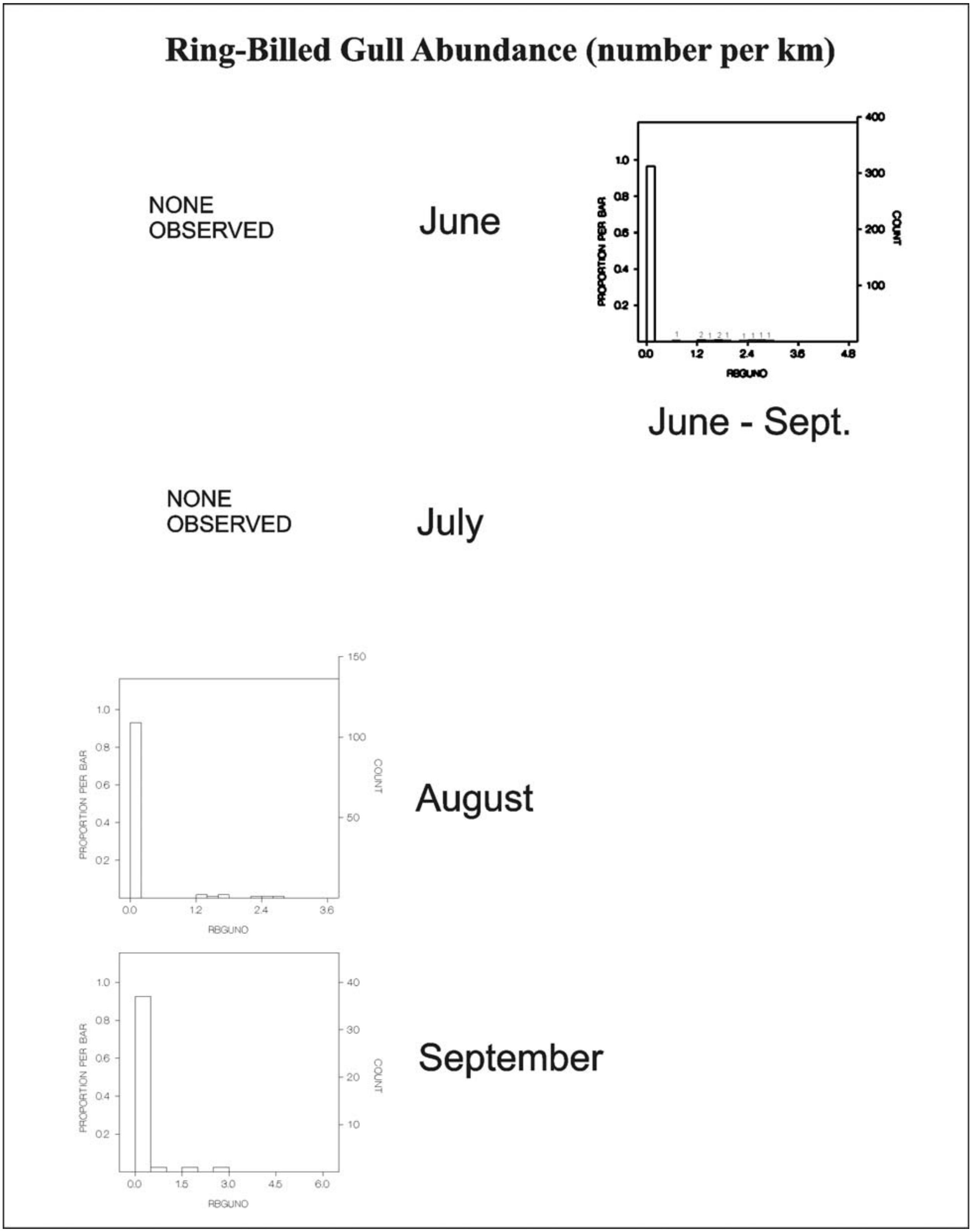

Figure 8. Monthly and overall frequency distribution of Ring-Billed Gull abundance per kilometre, including birds observed further than 300 m from survey vessel, June to September 2009.

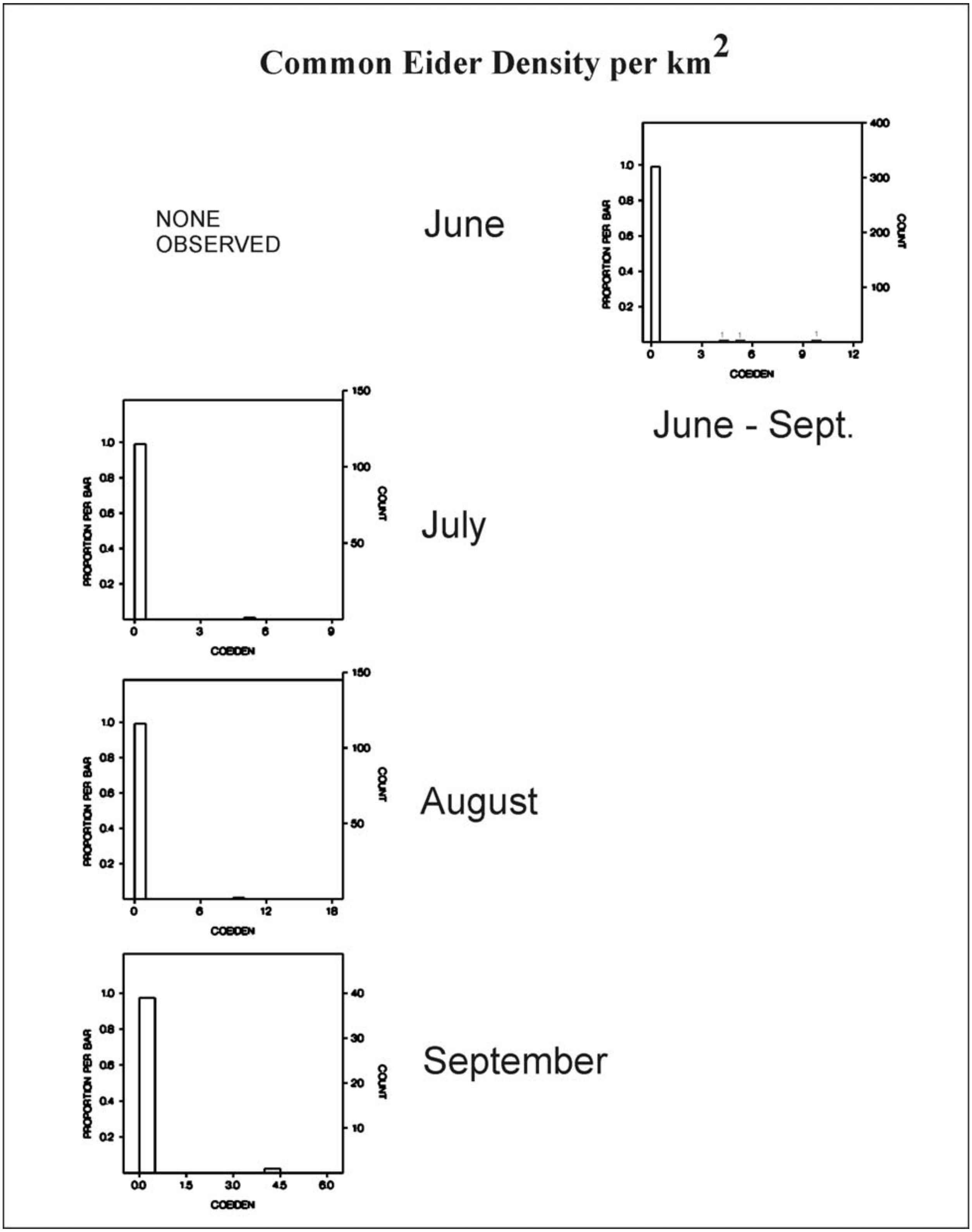

Figure 9. Monthly and overall frequency distribution of Common Eider density per km^2, determined from sightings within 300 m of survey vessel, June to September 2009.

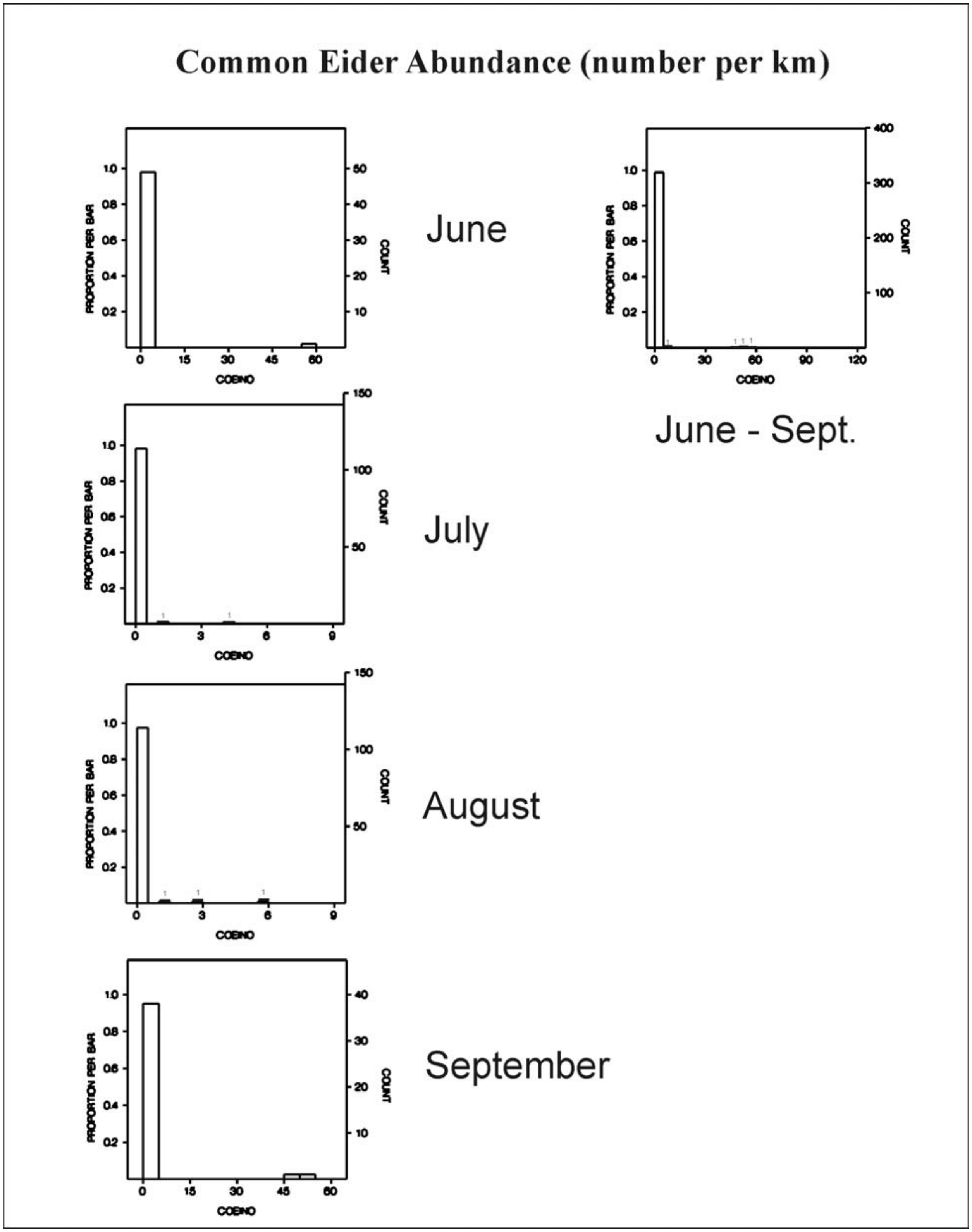

Figure 10. Monthly and overall frequency distribution of Common Eider abundance per kilometre, including birds observed further than 300 m from survey vessel, June to September 2009.

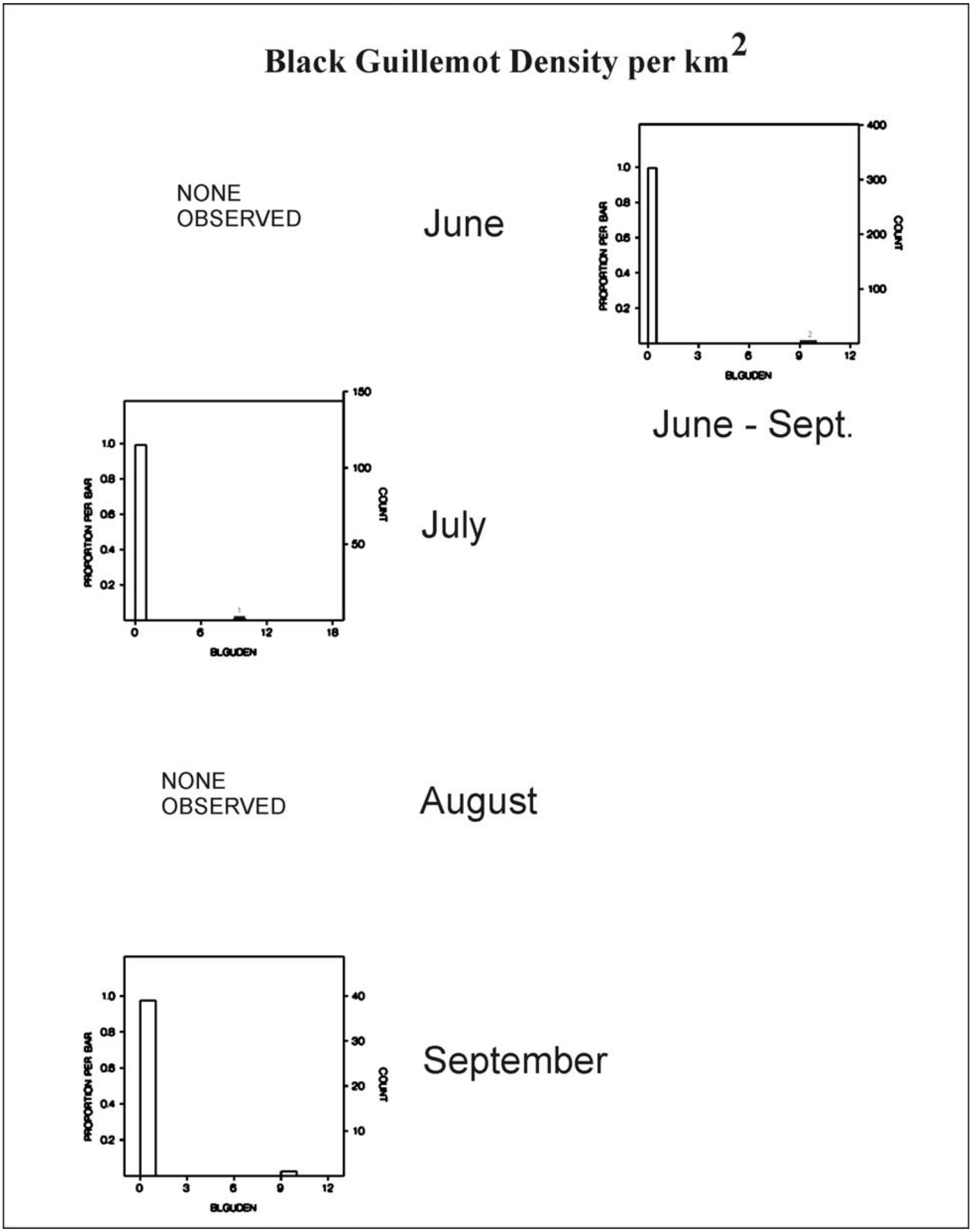

Figure 11. Monthly and overall frequency distribution of Common Eider density per km^2, determined from sightings within 300 m of survey vessel, June to September 2009.

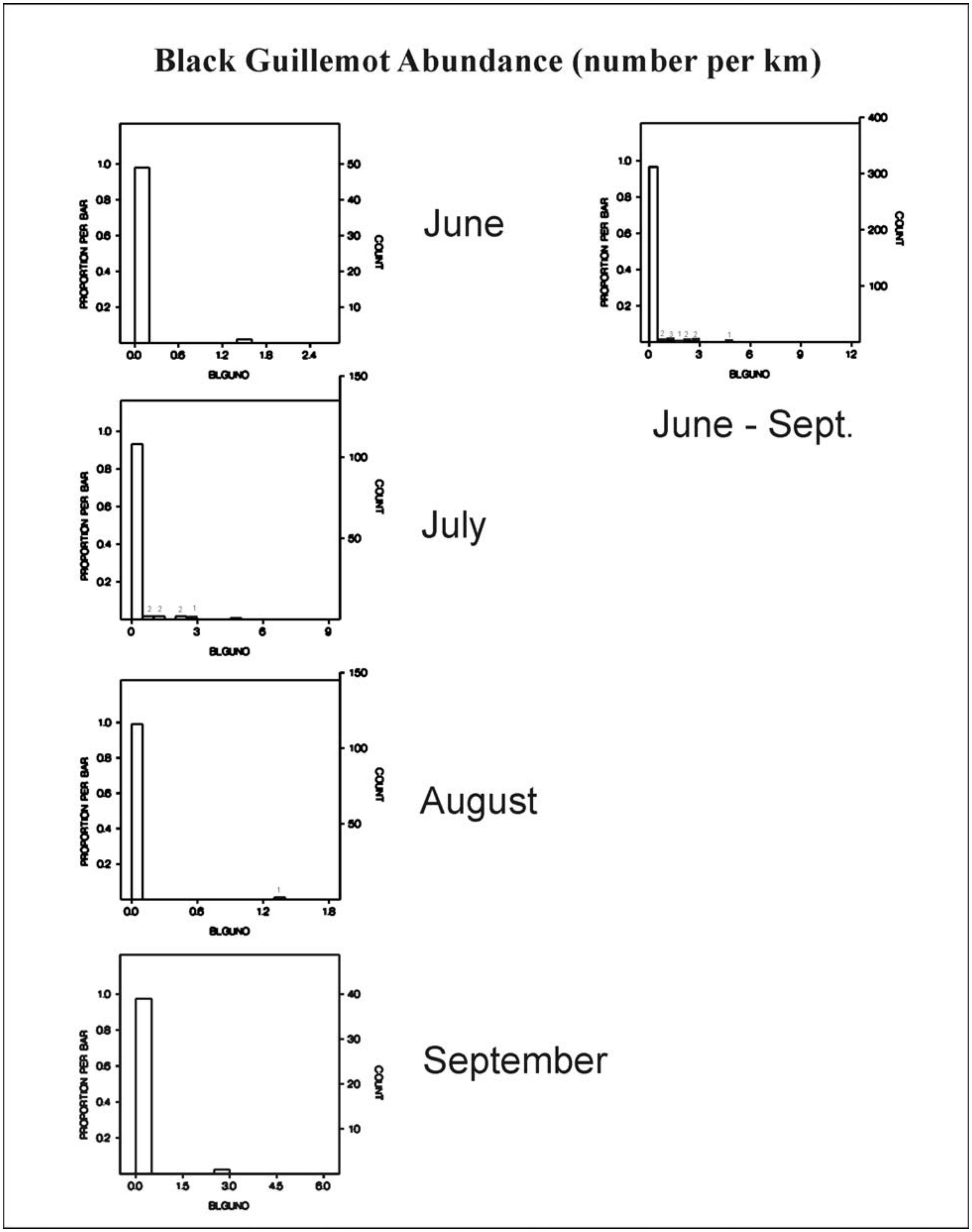

Figure 12. Monthly and overall frequency distribution of Black Guillemot abundance per kilometre, including birds observed further than 300 m from survey vessel, June to September 2009.