Spatial and temporal distribution of Atlantic brant

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ABSTRACT

Between January and March in 2002 and 2003, we captured Atlantic brant (*Branta bernicla hrota*; hereafter brant) and attached 59 very high frequency (VHF) transmitters and 22 platform transmitter terminals (PTTs) to investigate annual patterns of spatial and temporal distribution. We identified 2 major staging areas: western Long Island, New York, USA and portions of James Bay in Québec and Ontario, Canada. We did not observe any brant using the historic migration route along the Atlantic Coast to stage in Sept Îsle, Québec in the St. Lawrence estuary. Timing of migration events varied between years with longer duration of staging in James Bay during 2002, when weather conditions were poor despite good conditions further north on the breeding grounds in the Foxe Basin. During the breeding season marked brant were found on the islands and eastern shoreline of the Foxe Basin, Southampton Island, and Coats Island, Nunavut, Canada. We found no evidence that brant from specific nesting areas had any fidelity to particular wintering areas. Wintering brant spent the most time in open water habitats. Time spent in developed areas decreased through winter as time spent in emergent herbaceous wetlands increased. Our results provide spatial and temporal data to improve brant production models based on breeding ground snowmelt conditions, assist in the development of breeding ground surveys, and direct bioenergetics modeling to critical locations throughout the range and annual cycle of brant. Predictions of annual brant productivity need to account for weather conditions on staging areas as well as breeding grounds. Our data can also be used as a pilot for planning winter ecology studies.

INTRODUCTION

The population of brant is relatively small (10-year mean: 151,150 birds; Klimstra and Padding 2009) and has historically been subject to dramatic fluctuations in abundance (Kirby and Obrecht 1982). This population is susceptible to major population declines as a result of winter food loss, severe winter weather, poor production, or over-harvest (Kirby and Ferrigno 1980, Reed et al. 1998). While hunting mortality has been carefully managed, other vital rates remain unknown. Improved monitoring of the breeding population size and distribution, annual production, hunting harvest, annual survival, and habitat conditions is essential to making appropriate management decisions (Reed et al. 1998).

The breeding distribution of brant is located around the Foxe Basin in the eastern Arctic, with important colonies on Southampton (along the Bell Peninsula and around East Bay), western Baffin (Cape Dominion), Prince Charles, Air Force, and North Spicer Islands (Reed et al. 1980, Gaston et al. 1986). There is some evidence that brant from specific breeding areas may have a high fidelity to certain wintering areas. Vangilder and Smith (1985) showed that the genetic characteristics of brant wintering in New Jersey differed from those in Virginia and New York, which corresponded to differences in "necklace" characteristics. Novak et al. (1989) supported this conclusion with genetic work, finding that brant on the Atlantic Coast did not exhibit complete random mating.

The majority of brant winter along the coasts of New Jersey and Long Island, New York. Lesser numbers of brant winter north to Massachusetts and south to North Carolina. Managers believe brant have been reliably surveyed on the wintering grounds in the past and that the annual Midwinter Waterfowl Inventory (MWI) serves as a good index of long-term population change (Kirby and Obrecht 1982, Heusmann 1999). In recent years brant numbers have increased in urban areas where flight restrictions may compromise the completion of the MWI. Productivity is also monitored on the wintering grounds through age ratio counts conducted annually during November. While essential for tracking the status of brant, these surveys do not provide information for the current year's productivity when hunting regulations are promulgated in July. Lacking breeding ground surveys, harvest regulations are currently based on the size of the previous winter population (i.e., MWI) with modification by anecdotal productivity reports from arctic field researchers, when available.

Historically brant migrated from wintering areas along the Atlantic coast to Sept Îsle, Québec, Canada on the St. Lawrence estuary. From there brant departed to the Ungava and James Bays before arriving in the Foxe Basin (Bent 1925, Lewis 1937). More recently, a direct flight from the mid-Atlantic coast to James Bay appears to serve as the main migration route (Erskine 1988). In 1990 and 1991, Reed et al. (1996) evaluated the use of habitats by geese in the key spring staging areas of James Bay, Québec. Given the importance of this area to brant, they recommended careful, regular monitoring of the eelgrass (*Zostera* spp.) meadows there as well as their use by brant.

For small populations like brant, where the potential harvest could easily exceed a sustainable level, managers need reliable annual production information at the time decisions about regulations are made (AGJV Technical Committee 2000). Currently, there is no survey of brant productivity conducted on the breeding grounds. For a period of time, predictions of brant productivity based on satellite imagery of the timing of snowmelt on the breeding grounds were available in July (i.e., "the snowmelt model"). These predictions were suspended when they proved unreliable, both under- and over-estimating production. The poor performance of these models was thought to occur because the snowmelt models used satellite imagery from a large portion of Baffin Island, rather than focusing on the specific habitats where brant nest. A first step in developing an improved satellite imagery snowmelt model or a breeding ground aerial survey is to clearly delineate the brant breeding grounds.

RESEARCH OBJECTIVES

1) Clarify the migration routes and timing of migration.
2) Clarify the locations and periods of use of staging areas in relation to current and historical distribution of eelgrass and other submerged aquatic vegetation (SAV) beds.
3) Clarify the boundaries of the breeding range and search for previously unknown breeding colonies.
4) Provide pilot information for a study of home range and habitat use of brant in winter.

METHODS

We captured brant using rocket nets on estuarine intertidal areas and lawn areas (e.g., parks, golf courses, and sports fields) between January and March, in 2002 and 2003. We attached transmitters to the heaviest adult males we could obtain, reasoning that they would likely be paired. Given their larger body mass, the transmitter load would be a smaller percentage of their body mass thereby minimizing any adverse effects of transmitters on migration. Both Gudmundsson et al. (1995) and Clausen and Bustnes (1998) demonstrated that paired brant migrated together and that transmitters did not negatively affect pair bonds during long distance migrations. We attached either VHF transmitters or PTTs to brant using a backpack harness made with Teflon ribbon. We affixed transmitters in the manner described by Malecki et al. (2001). We attempted to distribute both types of transmitters in proportion to the distribution of wintering brant along the Atlantic coast, based on MWI data.

VHF transmitters weighed 28 g and had an expected battery life of 180 d. Once marked, brant were located weekly in New York and New Jersey and bi-weekly in Virginia, Maryland, and Connecticut via triangulation. During 2002 and 2003, 7 and 6 aerial flights were made to locate VHF-marked brant, respectively. The coverage of these flights varied from local (e.g., coastal New Jersey and Long Island, New York) to extensive (e.g., North Carolina to Massachusetts). We also attempted to locate VHF-marked brant on known and traditional stopover, staging, and breeding areas via aerial flights. During 2002, we conducted flights on 16, 22, and 30 May along the St. Lawrence River, and on 29 May and 4 and 11 June along the eastern and western coastlines of James Bay and Akimiski Island, Nunavut. On the breeding grounds, 5 flights were made on 30 June and 1, 2, 3, and 4 July along the coastlines of islands and mainland of the Foxe Basin (Figure 1). During 2003, the St. Lawrence River and the eastern coastline of James Bay were not surveyed. On 1 and 2 June flights were made along the western coast of James Bay and Akimiski Island. Flights were made on 30 June and 1, 2, and 4 July on the breeding grounds within the Foxe Basin (Figure 1). Flight altitudes varied from 150 m to 1,500 m.

PTTs weighed 30 g and had an expected battery life of 750 transmission hours. Duty cycles on PTTs were programmed to transmit for 8 h every 5 d from mid-December through February (winter period), every 3 d from March through June and September through mid-December (spring and fall migration), and every 7 d from July through August (breeding period).

The locations of PTTs were estimated based on the Doppler shift of a PTT signal during a satellite overpass and classified into locations classes (LCs) with different levels of accuracy (Service Argos 1996). The ARGOS system provided pairs of location estimates; a "location" which had greater frequency continuity and was supposedly the more likely estimate and an "image" which was an alternative estimate to the "location" (Britten et al. 1999). We contracted with Dr. Susan Sheaffer, Cornell University, to interpret the location data we received from ARGOS. The data were interpreted using the two-part sorting process described by Malecki et al. (2001) to select the most plausible and representative location during a satellite overpass. The first part of the sorting process identified the most plausible location from the location pair. The second part selected the most representative location from those collected during a single satellite overpass. LCs 3, 2, and 1 had reported accuracy < 1,000 m, LC 0 > 1,000 m, and LCs A, B, and Z did not receive enough transmissions for accuracy to be evaluated. Recent field tests have shown that poor quality locations (i.e., A, B, and Z) are often within 20-35 km of estimated locations (Britten et al. 1999, Green et al. 2002). Therefore, we considered locations from all LCs adequate to describe the large-scale annual movements of brant, but used the highest quality locations available whenever possible. We plotted the location estimates and analyzed movements using a geographic information system (ArcMap 9.3, Environmental Systems Research Institute, Redlands, California, USA).

We established 3 biologically significant regions to describe the annual movements of brant. These regions corresponded to the wintering, migration, and breeding periods: Atlantic Coast (<41.5˚N), James Bay (>51˚N and <55.5˚N), and Foxe Basin (>62˚N), respectively. These regions have been previously described as important areas within the annual range of Atlantic brant (Reed et al. 1998).

Migration routes and timing of migration

We identified migratory pathways using both VHF and PTT data. For VHF data, we connected locations that were > 20 km between successive locations for birds that were located at least once in each region. Aerial surveys for VHF-marked brant were not flown in James Bay or the St Lawrence River during the fall migration. Therefore, VHF data were only used to identify migratory pathways during spring migration. For PTT data, we connected locations that were separated by > 20 km and did not make direction reversals. These data provided migratory pathways during spring and fall migration as well as the timing of movements. Because PTT data were not received continuously, we defined temporal movements between regions using the last date a bird was located in a region and the first date it was located in the subsequent region.

Location and use of staging areas

To identify important stopover and staging areas, we divided the spring and fall migration periods into 5-day segments and selected a representative location for each bird during each segment. We originally intended to use the location selected by the sorting process corresponding to the duty cycles of PTTs during migration (i.e., 3-day). Due to the staggered capture of brant and deployment of transmitters, PTTs deployed later in the spring continued to acquire locations on a 5-day duty cycle during spring migration and a 7-day duty cycle during fall migration (i.e., those corresponding to winter and summer duty cycles, respectively). Representative locations were chosen based on the highest quality LC. If there were multiple locations of the same LC in a segment, one was chosen at random. Vangilder et al. (1986) considered Long Island an important location for staging brant to store energy necessary to fuel migration and reproductive efforts. Therefore, we extended 3 5-day segments prior to the initiation of the spring migration period of each bird to capture these movements and identify important staging areas of migratory brant within the Atlantic Coast region. We used the Kernel Density tool in ArcMap to evaluate the distributional use of the selected PTT locations during the spring and fall migrations. We were unable to locate suitable eelgrass or other SAV databases that were of sufficient temporal or spatial scale to permit an assessment of brant utilization of these habitats.

Breeding range boundaries

To delineate the breeding range of brant, we plotted a single nesting season location for each VHF- and PTT-marked brant. Brant are limited to a single nesting attempt (Barry 1962). Ankney (1984) identified the initiation of egg laying as 20 June and the end of incubation as 13 July. We used these dates to represent the nesting period. If a VHF-marked brant was located at multiple locations during our aerial flights between these dates we used the earliest location. For each PTT-marked brant we used the earliest, highest quality LC received during the nesting period, provided it had completed migration as indicated by movements < 20 km. We used the Kernel Density tool in ArcMap to evaluate the distributional use within the breeding range of the combined nesting season locations.

We investigated the possibility that brant from specific breeding areas may have a high fidelity to certain wintering areas by using capture locations as representative winter locations. Neither PTT- nor VHF-marked brant showed a propensity for movement between January and March. Data from 1 PTT-marked brant extended through 2 breeding seasons so we selected a representative location between January and March as this brant's winter location during the second season. We subdivided the Atlantic Coast region into 5 sub regions including (1) Virginia, Maryland, and Delaware, (2) southern New Jersey, (3) northern New Jersey, (4) New York, and (5) Connecticut and assigned winter locations to one of these sub regions. Representative summer locations were plotted by sub region to visually identify patterns of distribution in the Foxe Basin region.

Winter home range and habitat use

We used all available locations within the Atlantic Coast region from VHF-marked brant and only locations with measurable accuracy (i.e., LCs 3, 2, 1) from PTT-marked birds to estimate home range size and to summarize the number of locations in various habitat types by wintering brant. We used the 2001 National Landcover Database (NLCD) as a base layer for summarizing locations by habitat type because of its continuous coverage throughout the Atlantic Coast region (Homer et al. 2007). We selected three habitat types biologically significant to wintering brant; open water (NLCD class 11), emergent herbaceous wetland (NLCD class 95), and developed (NLCD classes 21, 22, 23, and 24). We summarized the number of data points occurring within each habitat type during early (arrival – 23 Jan), middle (24 Jan – 23 Mar), and late (24 Mar – departure) winter periods based on mean arrival and departure dates. We used a chi-square test of independence to determine if the summarized locations in various habitat types differed among transmitter type ($\alpha = 0.05$). We were unable to calculate the home range of wintering brant due to small sample size of accurate locations.

RESULTS

Brant were trapped at 13 locations in 5 states throughout their winter range (Figure 2). During 2002, 34 VHF transmitters and 10 PTTs were deployed (Table 1). During 2003, 25 VHF transmitters and 12 PTTs were deployed. We obtained 682 locations from VHF transmitters. We received 12,190 PTT locations from ARGOS. The sorting process identified 1,441 of these locations as representative locations, of which 665 locations (46%) had measurable accuracy.

Migration routes and timing of migration

We identified spring migration routes for 15 VHF-marked and 16 PTT-marked brant (Figures 3 and 4, respectively). During spring migration, PTT-marked brant arrived in the southern portion of the James Bay region near Rupert Bay. Fourteen of 16 brant moved up the western shore of James Bay during the duration of their stay in the region. The remaining 2 brant arrived in the Rupert Bay portion of the James Bay region and spent the entire time there before departing for the Foxe Basin region. Two VHF-marked birds were located in Rupert Bay, Québec and located during subsequent aerial telemetry flights near Fort Albany, Ontario corroborating movements of PTT-marked brant. During spring migration we observed no use of the eastern shore of James Bay north of Rupert Bay. The mean distance travelled by PTT-marked brant from the Atlantic Coast region to the midpoint of movements within the James Bay region was 1,489 km (± SE 47). The mean distance travelled by PTT-marked brant from to the midpoint of movements within the James Bay region to their inferred nesting location in the Foxe Basin region was 1,720 km (± SE 75).

None of the PTT-marked brant moved along historical Atlantic Coast migration routes through the New England states and the Atlantic Maritime provinces to Sept Îsle, Québec on the St. Lawrence estuary. We did however detect signals from 2 VHF-marked birds at several locations in Québec along the St. Lawrence estuary west of Sept Îsle; on 16 May at Kamouraska, on 22 May at île-aux-Fraises, and on 30 May near Rimouski. We did not obtain earlier locations that would allow us to determine whether these birds moved north along the Atlantic Coast or if they moved north through the Hudson and Champlain Valleys and then east along the St Lawrence River. One of these brant was subsequently located in both the James Bay and Foxe Basin regions and the other only in the Foxe Basin region.

We identified fall migration routes for 12 PTT-marked brant (Figure 5). During fall migration we observed 3 of 12 PTT-marked brant use the eastern shore of James Bay north of Rupert Bay. PTT-marked brant generally exhibited a direct flight between the James Bay and Atlantic Coast regions during fall migration.

Timing and duration of migratory events varied more during spring migration than fall migration (Table 2). Despite departing the Atlantic Coast region an average of 5 d earlier, brant took longer to arrive in the James Bay region and remained there longer in 2002 than 2003. Subsequently, they departed the James Bay region 4 d later. The timing and duration of the breeding season and fall migration was similar in both years.

Location and use of staging areas

During spring migration, we identified a high density of PTT locations at 1 location in the Atlantic Coast region and 2 locations in the James Bay region (Figure 6). Many brant made movements to Long Island, New York prior to leaving the Atlantic Coast region during spring migration. Ten out of 14 (71%) PTT-marked brant wintering south of Long Island, New York (i.e., northern New Jersey, southern New Jersey, and Virginia, Maryland, and Delaware sub regions of the Atlantic Coast region) migrated to western Long Island, New York, before departing the Atlantic Coast region. Brant that wintered on Long Island remained there until they departed the Atlantic Coast region. Brant that wintered north of Long Island (i.e., Connecticut sub region of the Atlantic Coast region) did not make use of Long Island, New York during spring migration, but departed directly from their wintering area. During spring migration, high densities of PTT locations within the James Bay region were located in Rupert Bay, Québec and the area between Attawapiskat, Ontario and Akimiski Island, Nunavut. During fall migration we identified a high density of PTT locations at 2 locations in the James Bay region; at Cape Henrietta Maria, Ontario and again at the area between Attawapiskat, Ontario and Akimiski Island (Figure 7). We observed less use of Long Island, New York during fall migration than during spring migration, however our ability to measure this was hampered by PTT failure during the fall and early winter. In addition to the areas indicated by a high density of locations, individual brant made use of large lake and river systems between the James Bay and Atlantic Coast regions during both fall and spring migrations. Specific areas identified included Lake Champlain, the north shore of Lake Ontario near Port Hope, Brighton, and Belleville, Ontario, the lower Ottawa River near the confluence with the St. Lawrence River, the St. Lawrence River near Montreal and Trois-Rivieres, Québec, and smaller lakes at the headwaters of the Harricana River near Val-d’Or, Québec. Between the James Bay and Foxe Basin regions, 1 bird stopped on the Belcher Islands, Nunavut and 1 bird stopped on the Ottawa Islands, Nunavut. Most brant apparently made the flight between these regions nearly non-stop, presumably owing to the presence of open water and absence of coastal islands and intertidal zones. Upon arrival in or departure from the Foxe Basin region, brant used islands and lowland areas as stopovers during migration.

Breeding range boundaries

A total of 43 brant were located in the Foxe Basin region between 20 June and 13 July (28 VHF, 15 PTT). One PTT-marked brant was tracked through 2 summers and provided 2 nesting locations, both on the south shore of Prince Charles Island despite wintering in 2 different locations (northern New Jersey in 2002 and Delaware in 2003). The majority of VHF- and PTT-marked brant migrated to nesting locations in the Foxe Basin near Bowman Bay and Cape Dominion on southwestern Baffin Island, Air Force Island, and Prince Charles Island. The density of locations in these areas was higher than on the southwest side of the Foxe Basin around Southampton Island (Figure 8). The most distant location occurred north of Repulse Bay, Nunavut (~66.82˚N, 86.82˚W) halfway between Repulse Bay and the southern end of the Gulf of Boothia. This location was first recorded on 24 June 2003 and never changed, indicating probable mortality or PTT loss. The nesting locations showed no association between breeding and wintering areas (Figure 9).

Winter home range and habitat use

We obtained 373 PTT locations and 597 VHF locations in the Atlantic Coast region, of which 89% and 96%, respectively, were located within our 3 designated habitat types. Overall habitat use throughout the winter did not differ between VHF- and PTT-marked brant (χ^2 = 1.696, df = 2, p = 0.428) so we combined PTT and VHF locations. Marked birds spent the greatest amount of time in open water habitats, presumably shallow water bay areas, during all winter periods (Figure 10). Brant used developed areas less frequently as the winter period progressed (Figure 10). Brant use of emergent herbaceous wetlands increased during the late winter period (Figure 10).

DISCUSSION

Migration routes and timing of migration

We found no evidence that brant used the historic coastal migration route through the New England states and Atlantic Maritime provinces to a staging area at Sept Îsle, Québec. Previously, the majority of brant were thought to have used this route (Bent 1925, Lewis 1937). Erskine (1988) concluded that changes in migration routes likely began during the 1930's when the first records of brant began to appear at Lake Ontario. This change likely occurred in response to the massive eelgrass die offs along much of the coastal migration route and in the St. Lawrence estuary during this time. Ward et al. (2005) supported this conclusion based on shifts in SAV abundance, making it less advantageous to use this coastal route. Despite our results there is evidence that some brant continue to use the coastal migration route. Several thousand brant were observed during spring migration on Grand Manan Island, New Brunswick and Cape Sable Island, Nova Scotia (A. Hanson, Canadian Wildlife Service, personal communication), as well as in the Gulf of St. Lawrence, Québec (P. Brousseau, Canadian Wildlife Service, unpublished data). A small flock of brant were observed on Brier Island, Nova Scotia during fall migration by PMC.

Timing and duration of spring migration varied annually (Table 2). Previously, the authoritative works on brant migration were limited to historical accounts from individual journal entries (e.g., Bent 1925, Lewis 1937). Our estimates of mean arrival and departure dates varied from those reported by Lewis (1937) and Barry (1962). Lewis (1937) reported that brant arrived at Rupert House (Waskaganish), Québec on 1 May and had moved on by the end of May. Our data indicated that brant first arrive, on average, in the James Bay region between 25 and 28 May and leave the region by 12 and 15 June. The disparity between the arrival dates that we observed and those that Lewis (1937) reported are nearly a month apart. Lewis (1937) reported that brant first arrived at different locations within the Foxe Basin region on the following dates: Gordon Bay, south Baffin Island 21 and 22 June, Bowman Bay 7 to 24 June, Southampton Island 18 and 19 June. Most of these dates are consistent with our mean arrival dates (Table 2). In contrast, Barry (1962) first observed brant on 7 and 8 June, nearly two weeks before our mean arrival dates of 18 to 20 June. These dates are as much as a week earlier than the dates of first arrivals that we observed; 15 June 2002 and 10 June 2003. Differences in arrival times among years are expected due to the effects of weather conditions at the wintering and staging areas. The small sample size of PTTs and their duty cycle could also influence our arrival date calculations.

Our results quantify the duration of segments of the annual cycle (Table 2). These data have useful application as many habitat Joint Ventures of the North American Waterfowl Management Plan move toward energetically-based habitat goals. Previously, assessments of brant productivity focused solely on breeding ground conditions. Our data demonstrates that environmental stochasticity can affect the duration of staging and arrival date on the breeding grounds, thereby influencing annual recruitment. Brant spent an average of 22.9 d (± SE 0.9) and 16.4 d (± SE 2.3) in the James Bay region during spring migration in 2002 and 2003, respectively. The mean number of days brant staged in the James Bay region in 2002 was significantly longer than in 2003 (Student's t-test; $t = 2.3693$, $p = 0.033$). We believe this was due to below average, unseasonably cold conditions present during 2002 throughout southern Canada up to about 61˚N latitude. Brant appear to have delayed their migration to the breeding grounds (Table 2) even though field biologists working in the Foxe Basin region reported good conditions there. Brant arrived on the breeding grounds earlier in 2003 having not been delayed by below-average conditions in the James Bay region. Fall productivity surveys indicated poorer production in 2002 (6.9% juveniles) versus 2003 (17.2% juveniles) (Klimstra and Padding 2009). Weather conditions in both the James Bay and Foxe Basin regions should be incorporated into future brant productivity models.

Location and use of staging areas

The staging area identified on western Long Island, New York was used by at least 71% of the brant wintering south of Long Island in addition to the large concentration of brant that wintered there. The number of marked brant that we observed using this area prior to spring migration may be biased low due to the non-continuous nature of PTT duty cycles or timing of VHF monitoring flights. As waterfowl managers begin to establish objectives for landscape carrying capacity based on energetic demand and supply, important considerations should be given to this region. In addition to the constant demand for energy by brant wintering on Long Island, models must also account for the additional use by a large proportion of the population wintering south of the region during the staging period. This period of time is critical for successful breeding. Given the duration of staging and fat deposition rates in European brent populations (Ebbinge 1989), it is unlikely that brant have enough time in the James Bay region to garner all the energy stores required to fuel migration and produce a clutch. Therefore, they must depart the Atlantic Coast region with adequate stores to arrive in the James Bay region with some minimum body mass. These stores are then replenished to complete migration and arrive in sufficient condition to successfully reproduce. Managers need to provide the habitat resources required to send brant north with adequate energy reserves to maintain the brant population. However, western Long Island is a highly urbanized area and providing additional high quality habitats may increase the potential for human/wildlife conflicts. In this area, growing numbers of large-bodied birds, including brant, have caused concerns over bird strikes to aircraft (Dolbeer 2009) as well as damage to and droppings on lawn areas of parks, golf courses, and sports fields (Smith et al. 1999).

The areas of high density use in the James Bay region (i.e., Rupert Bay, Québec, the area between Attawapiskat, Ontario and Akimiski Island, and Cape Henrietta Maria) appeared to function as stepping stones along the western shore of James Bay during the staging periods. During spring migration, brant arrived first at Rupert Bay, the southernmost location in the James Bay region. Presumably this is the first available food source after completing this leg of their migration. From there brant moved northwest to the area between Attawapiskat, Ontario and Akimiski Island, Nunavut, and from there most brant departed for the Foxe Basin region. During fall migration brant arrived at Cape Henrietta Maria, the northernmost point on the west shore of James Bay. Brant then moved southeast to the area between Attawapiskat, Ontario and Akimiski Island, Nunavut from which most brant departed for the Atlantic Coast region. Interestingly, brant neither moved farther northward toward Cape Henrietta Maria during spring migration nor farther southward toward Rupert Bay during fall migration. These movements would have reduced the migratory distances covered without refueling by approximately 250-300 km each way.

The relatively higher intensity use of the western shore (Ontario) compared to use of the eastern shore (Québec) of James Bay was noteworthy. Reed et al. (1996) documented brant use of the eastern shore of James Bay. Certainly the presence of vast eelgrass meadows and many salt marshes along the northeastern coast of James Bay documented by Dignard et al. (1991) and Lalumiére et al. (1994) provided excellent habitat for brant at that time. A more recent study conducted in 2005 showed a decline in the quantity of eelgrass meadows (Short 2008). The author concluded that this decline was most likely caused by the decreased salinity in coastal bays resulting from discharges of freshwater from the operation of hydro-electric plants on several major rivers in the area. The study suggested that other hypotheses including disease, isostatic uplift, and climate change were not likely the cause of the observed decline. Studies of brant harvest by aboriginal hunters in James Bay showed that in the 1970s the harvest of brant per hunter was much higher in Québec than in Ontario; 6.1 brant per Cree hunter per year in coastal Québec versus 0.25 on the Ontario side of James Bay (calculated from Prevett et al. 1983, NHRC 1982, NHRC 1988). In 2009, Cree hunters reported that over the last decade brant have been scarce along the eastern shore of the James Bay north of Rupert Bay during spring migration (R. Cotter, Canadian Wildlife Service, personal communication). While not conclusive, this information suggests that during the 1970’s brant were more abundant in Québec.

The large lake and river systems between the James Bay and Atlantic Coast regions that we identified as stopovers between major staging areas showed little use by brant. These areas lie within the Atlantic Coast and Eastern Habitat Joint Ventures. Presumably, brant stop briefly in these areas to rest, drink, or occasionally forage. However, it appears that brant rely primarily on lipid resources accrued elsewhere to fuel migration. Therefore, management of these areas should ensure protection of water resources to provide interim stops for migrating birds.

Breeding range boundaries

We explored the northwestern edge of the Atlantic brant breeding range (Gaston et al. 1986) by flying the Fury and Hecla Strait, Agu Bay, Bernier Bay, and Berlinguet Inlet areas of northwestern Baffin Island, Nunavut. We also searched the northeastern coast of Hudson Bay from Kettlestone Bay to Ivujivik, Nunavik, Québec. We did not find any brant in these areas. The brant that died northwest of Repulse Bay, Nunavut was located in rugged terrain at the base of the Melville Peninsula, which is not in typical brant habitat. However, if this brant had continued along its flight trajectory, it would have ended up in the Gulf of Boothia, which is west of the described breeding range of Atlantic brant.

We did not identify extensions of the breeding range into any previously unknown regions. The density of summer locations that we observed (Figure 8) was very similar to those observed during aerial flights of the Foxe Basin region by Gaston et al. (1986). These data should be used to reassess the allocation of banding efforts on the breeding grounds and to develop an improved satellite imagery snowmelt model. These data have been provided to the Canadian Wildlife Service (CWS) and US Fish and Wildlife Service for use in developing a breeding ground aerial survey.

We were unable to identify any discernable affinities between wintering and breeding areas. Vangilder and Smith (1985) examined differential distribution of birds on the wintering grounds based on "necklace" characteristics. The authors concluded that differential distribution occurred on the wintering grounds and that this may be linked to contributions from brant from different breeding areas. Novak et al. (1989) found that gene flow among wintering populations was somewhat restricted and attributed this to female philopatry and familial cohesiveness. Our data did not support these conclusions, although the morphological and genetic studies suggested that links might occur at a much smaller scale than our study was able to detect.

Winter home range and habitat use

We were able to glean very little novel information regarding use of habitats or home range during winter. Marked birds frequented open water habitats, presumably in shallow water bay areas. The decrease in brant use of developed areas over winter may be explained by a decreased reliance on upland fields, parks, and recreational areas for foraging and the cessation of the hunting season. Similarly, the increased use of wetland emergent habitat during the late winter period may be explained by the initiation of growth of *Spartina alterniflora* at that time. Kirby and Obrecht (1980) demonstrated that *Spartina alterniflora* had a greater energetic value than eelgrass or sea lettuce (*Ulva lactuca*), having 4.28 kcal/g [dry], 3.50, and 3.48, respectively. Our summary of locations by habitat type should however be received with caution because we were unable to assess the statistical significance of these interactions. Data from PTT-marked brant provided an adequate number of locations but very few were accurate enough to draw conclusions at this scale. Even locations of LC 3 which had a stated accuracy of < 150m were only accurate to this level 67% of the time. Data from VHF-marked brant provided more consistently accurate locations but the monitoring protocol (i.e. weekly in New Jersey and New York, biweekly in other states) did not produce a large number of locations. For these reasons we were unable to calculate individual home ranges. These winter location data are available for researchers interested in determining sample sizes and distribution of radios for studies of brant winter spatial ecology. Given our results, it is likely that a PTT-based study would benefit from use of GPS technology and a shorter duty cycle. Alternatively, a VHF-based study should employ more frequent monitoring and employ an explicit measure of location error. These data were consulted in establishing study areas for an ongoing Atlantic Flyway study of brant energy demand and food use.

Other products and benefits

In addition to investigating the original objectives outlined in this report, we have also identified additional research objectives that will be explored with our data. From our PTT data set we will be able to estimate flight speed during migration utilizing methods described by Miller et al. (2005). Using our knowledge of spring migration routes and the spatial and temporal use of staging areas for refueling in conjunction with models of mechanical flight theory, we will quantify the energetic costs of migration. From this we will develop minimum mass criteria for adult female brant to successfully reach the breeding grounds and lay and incubate a clutch of eggs. Our minimum mass criteria should allow managers to annually assess the breeding condition of brant each spring. In addition to determining if spring migration is a period of limitation overall, our criteria should allow managers to determine where and when any limitations might occur.

This study has also been used to educate the public about Atlantic brant, the importance of habitat in their life cycle as well as the complexities and information needs regarding management of this migratory game species. Information on brant biology and the study has been posted on the New Jersey Division of Fish and Wildlife website, available at http://www.njfishandwildlife.com. The site also recognizes the international partners participating in the study, describes the study objectives and methods, and contains maps of the movements of PTT-marked brant. An informational article regarding this study, along with maps and photos, was published in the New Jersey Hunting Digest. An article was also written for the New Jersey Waterfowler's newsletter and an interview was given and photos taken for the Atlantic City Press. The CWS National Office distributed a poster detailing this work to all the northern communities.

During 2002, we shared our Foxe Basin survey flight with biologists from several CWS offices to benefit the Nunavut Habitat Program, the Eastern Arctic Goose Banding Program, and to improve general knowledge of bird distribution in the area. Al Fontaine (CWS-Nunavut Region) recorded information to use in habitat interpretation of satellite images. Dale Caswell (CWS-Winnipeg Office) recorded information regarding the distribution and phenology of nesting geese to improve the distribution and timing of banding efforts. Steve Wendt (CWS-National Office) recorded geo-referenced wildlife observations along flight paths, wherever we flew low enough. In addition to bird observations, polar bear (*Ursus maritimus*), beluga whale (*Delphinapterus leucas*), and walrus (*Odobenus rosmarus*) observations were recorded and provided to marine mammal biologists.

During 2003, we shared our Foxe Basin flight with a David Golden, a biologist from the New Jersey Division of Fish and Wildlife's Endangered and Nongame Species Program, who searched for VHF-marked red knots (*Calidris canutus*). Daniel Bordage (CWS-Québec Office) recorded geo-referenced wildlife observations along flight paths, wherever we flew low enough. Several greater snow goose (*Chen caerulescens*) colonies were surveyed and other bird, narwhal (*Monodon monoceros*), beluga whale and walrus observations were recorded and provided to CWS biologists.

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Table 1. Number of male Atlantic brant marked in the Atlantic Coast region and distribution of very high frequency (VHF) or platform transmitting terminal (PTT) type transmitters used to determine the spatial and temporal movements between wintering, staging, and breeding areas, January-March, in 2002 and 2003.

State	Year	Brant Marked PTT	Brant Marked VHF	% total of PTT and VHF transmitters deployed per state	% of population surveyed during MWI, 1997-2001[b]
New Jersey	2002	6	16		
	2003	4	11	46%	66%
New York	2002	3	15		
	2003	4	8	37%	18%
Virginia	2002	1	3[a]		
	2003	2	5[a]	14%	12%
Connecticut	2002	0	0		
	2003	2	0	2%	0.1%
Maryland	2002	0	0		
	2003	0	1	1%	1%
All States	2002	10	34		
	2003	12	25		
Total	2002-2003	22	59		

[a]Indicates that one VHF transmitter attached to a female Atlantic brant.

[b]Klimstra and Padding (2009).

Table 2. Mean timing and duration (days) of movements for Brant migrating between winter (Atlantic Coast), spring staging (James Bay), and summer (Foxe Basin) regions, in 2002 and 2003.

				Departure/Arrival Dates					
			n	Mean	SE	Observed Range			Duration
2002	Spring	Depart Atlantic Coast	8	17-May	1.6	10-May	to	22-May	7.1
		Arrive James Bay	8	24-May	0.9	21-May	to	28-May	22.9
		Depart James Bay	7	16-Jun	1.4	12-Jun	to	22-Jun	3.6
		Arrive Foxe Basin	7	20-Jun	1.4	15-Jun	to	25-Jun	77.5
	Fall	Depart Foxe Basin	6	6-Sep	3.0	24-Aug	to	13-Sep	6.3
		Arrive James Bay	6	12-Sep	2.7	31-Aug	to	15-Sep	37.0
		Depart James Bay	6	19-Oct	3.6	6-Oct	to	27-Oct	5.0
		Arrive Atlantic Coast	6	24-Oct	4.0	9-Oct	to	4-Nov	210.0
2003	Spring	Depart Atlantic Coast	11	22-May	1.8	15-May	to	29-May	5.3
		Arrive James Bay	10	28-May	2.3	18-May	to	4-Jun	16.4
		Depart James Bay	9	12-Jun	2.0	5-Jun	to	22-Jun	5.4
		Arrive Foxe Basin	9	18-Jun	2.1	10-Jun	to	23-Jun	78.2
	Fall	Depart Foxe Basin	6	4-Sep	1.9	30-Aug	to	12-Sep	5.7
		Arrive James Bay	6	10-Sep	2.5	3-Sep	to	20-Sep	36.3
		Depart James Bay	6	16-Oct	2.5	7-Oct	to	25-Oct	5.0
		Arrive Atlantic Coast	6	21-Oct	3.9	10-Oct	to	7-Nov	---[a]

[a]Duration of winter period was not calculated because batteries on PTTs expired prior to departure from the Atlantic Coast region in spring 2004.

Figure 1. Survey routes flown in the Foxe Basin region to search for VHF-marked brant from 30 June through 4 July, in 2002 and 2003.

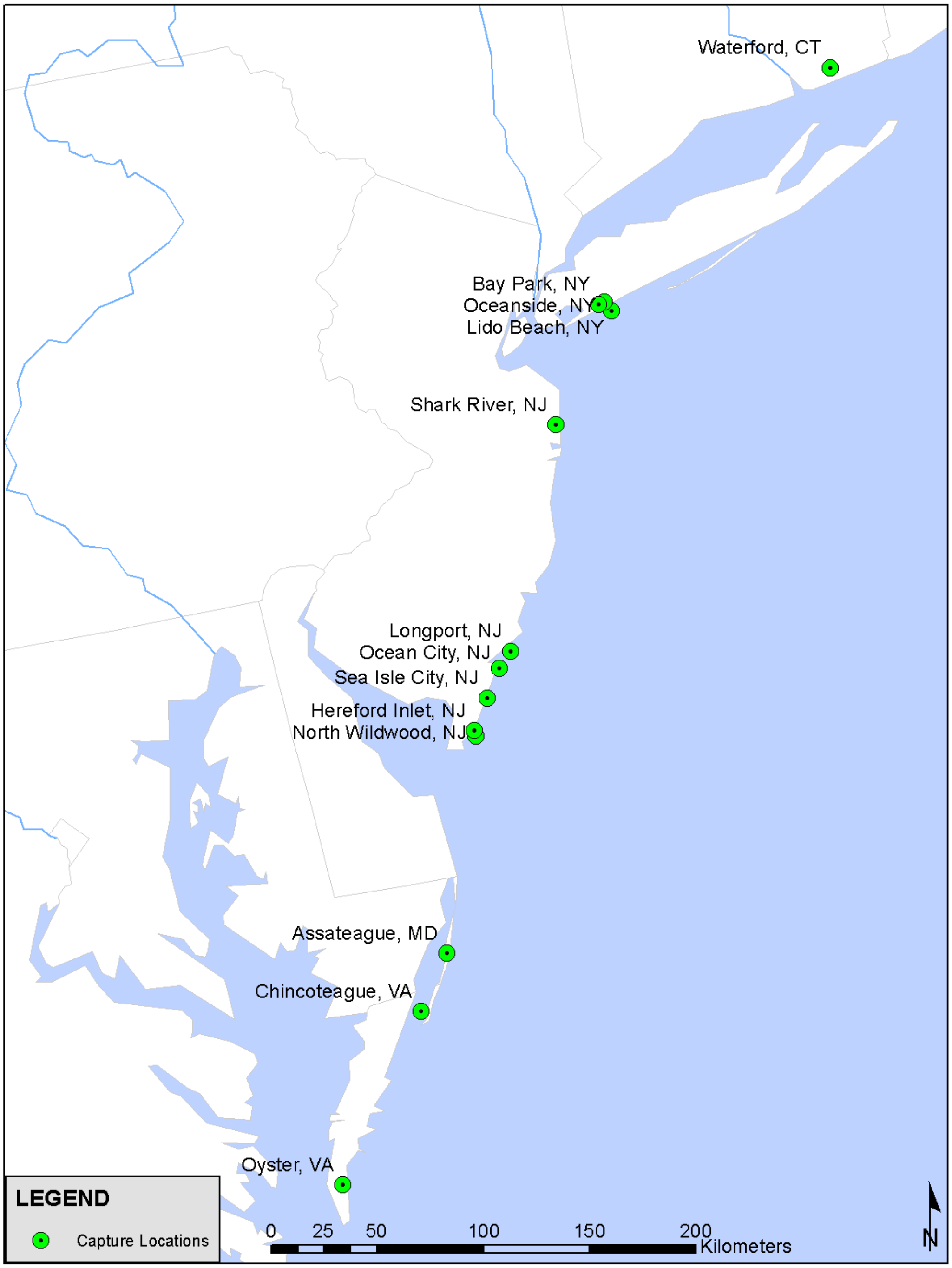


Figure 2. Capture locations throughout the winter range of Atlantic brant. Adult males were marked, during the period January-March, in 2002 and 2003, with either a PTT or VHF type transmitter to determine the spatial and temporal movements between wintering, staging, and breeding areas.

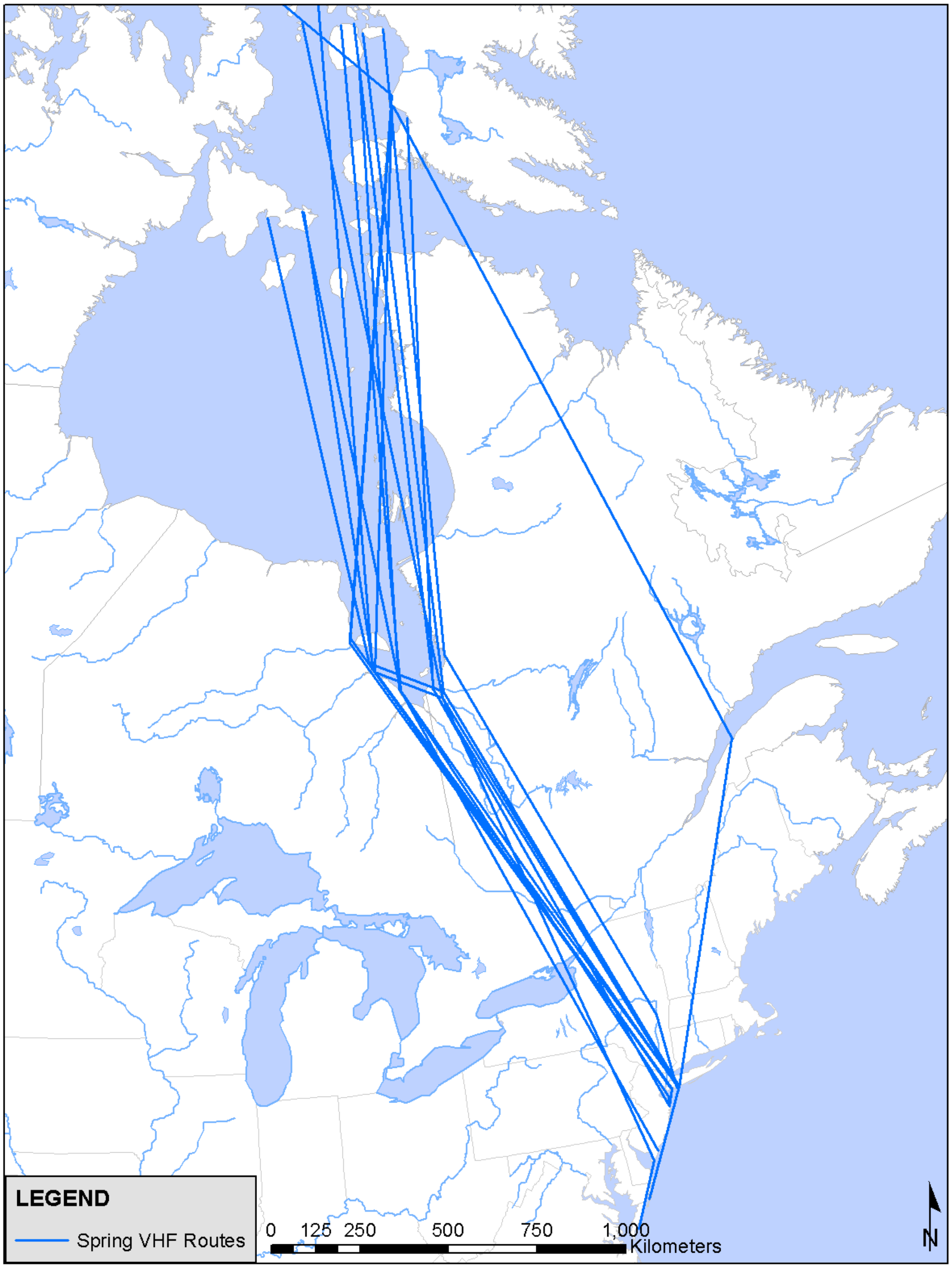


Figure 3. Spring migration routes of VHF-marked Atlantic brant (n = 15), in 2002 and 2003. Migration routes of VHF-marked brant appear direct because only single locations were acquired within the James Bay and Foxe Basin regions and no locations were acquired between regions.

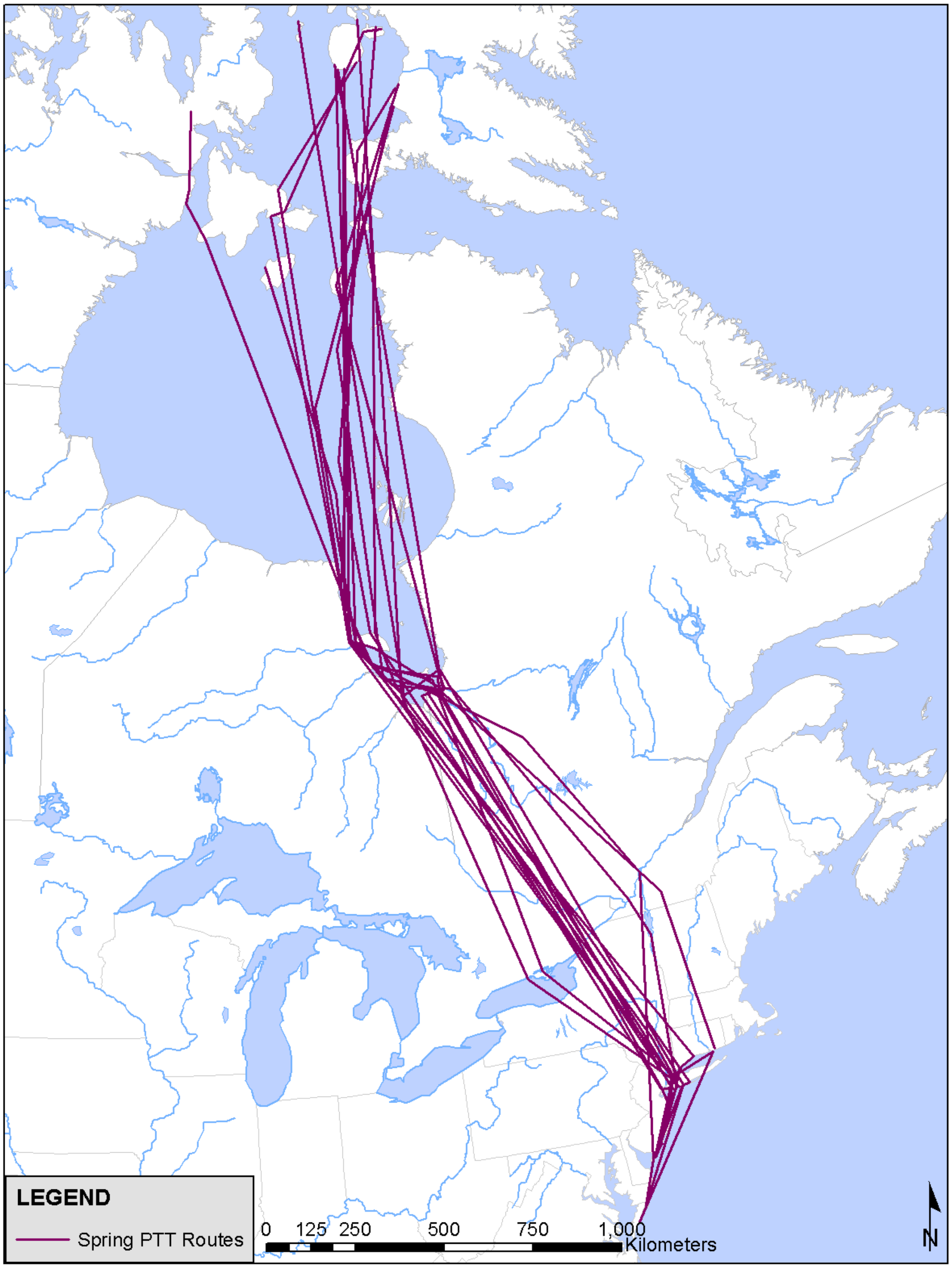


Figure 4. Spring migration routes of PTT-marked Atlantic brant (n = 16), in 2002 and 2003.

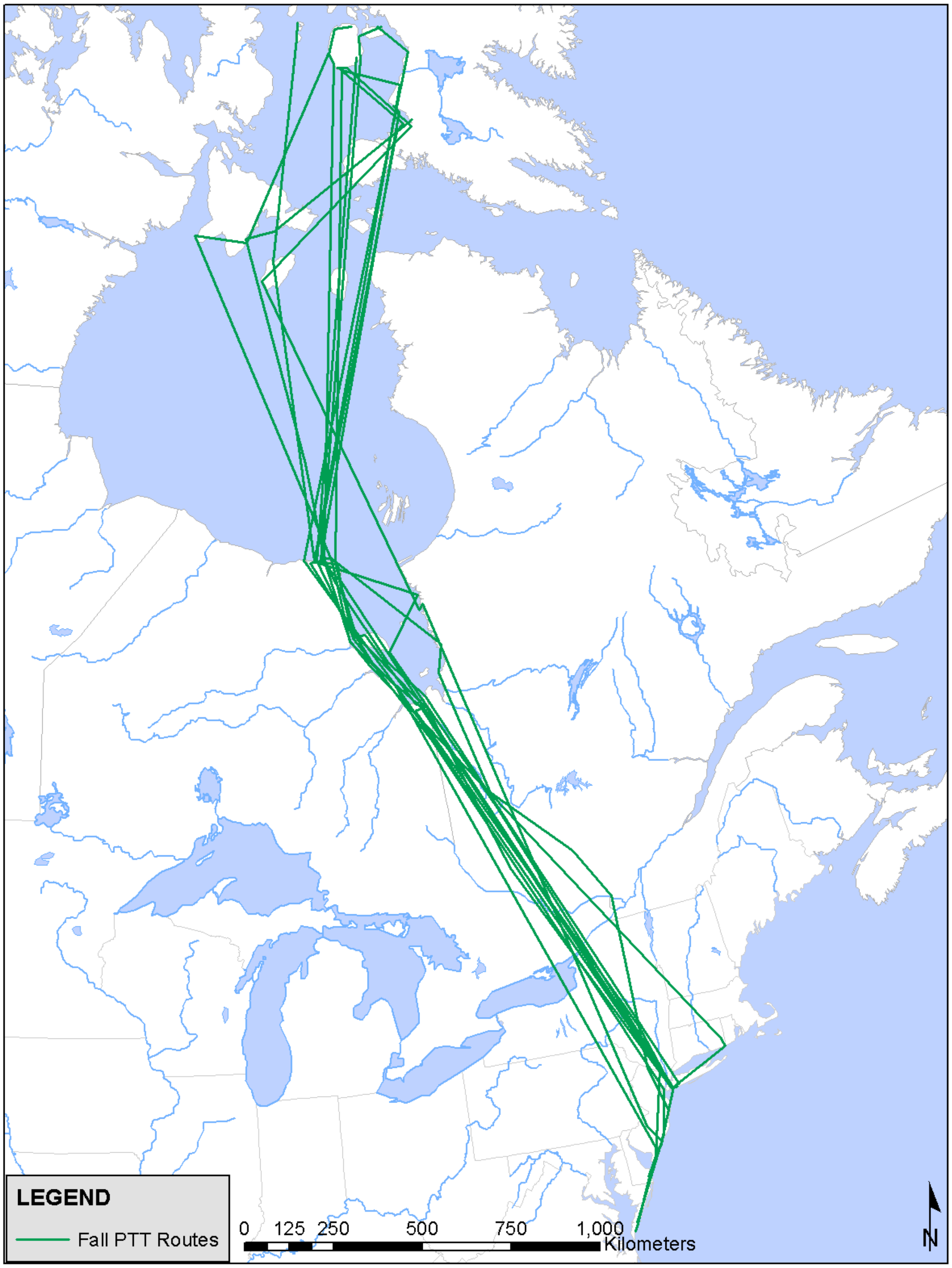


Figure 5. Fall migration routes of PTT-marked Atlantic brant (n = 12), in 2002 and 2003.

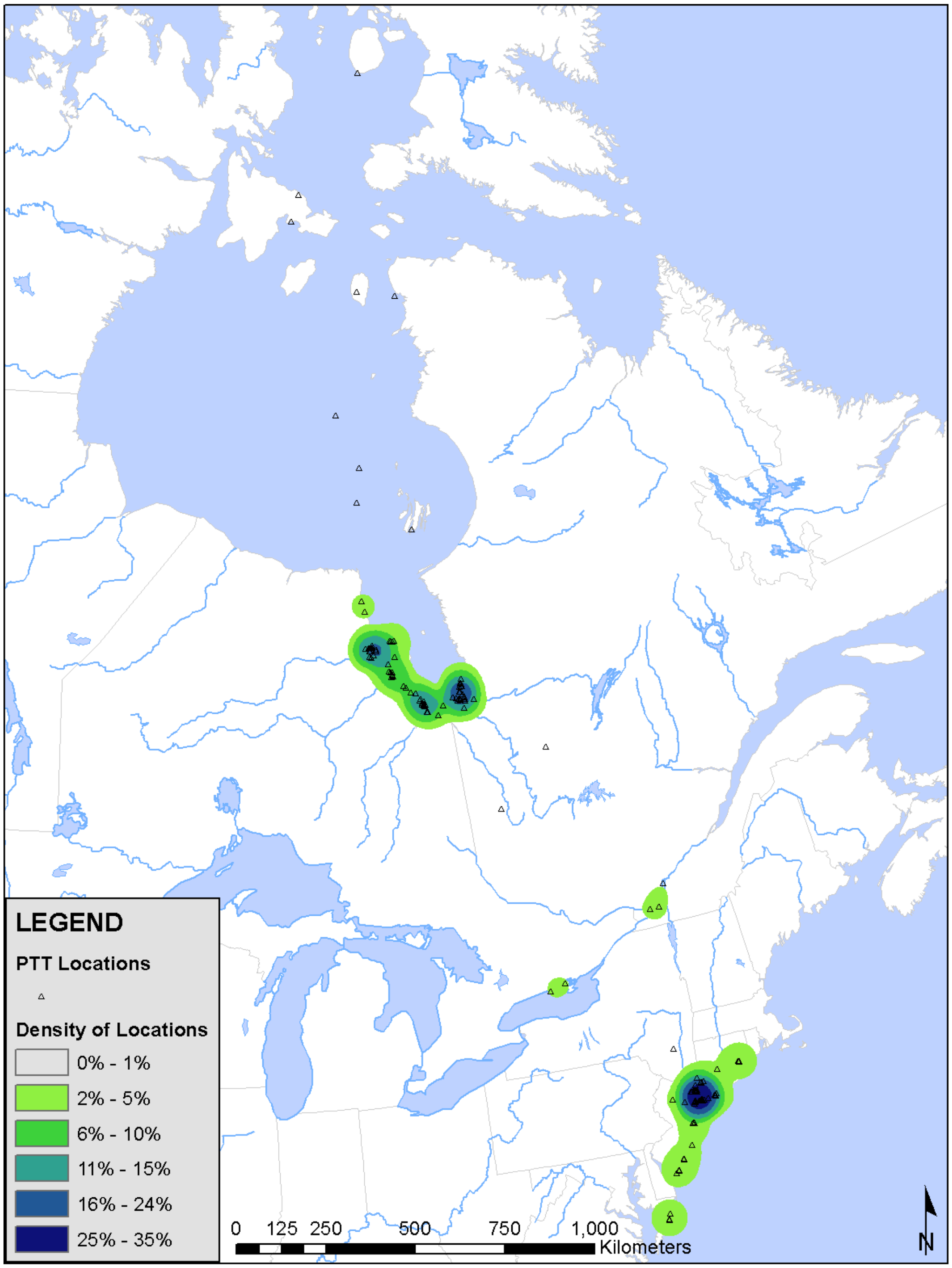


Figure 6. Locations and density of locations for PTT-marked brant during spring migration. Spring migration for each brant was defined as the period between 15 d prior to its last known date in the Atlantic Coast region and its first known date in the Foxe Basin region. We extended the period to include the 15 d prior to the last date in the Atlantic Coast region in order to capture migratory movements within the region.

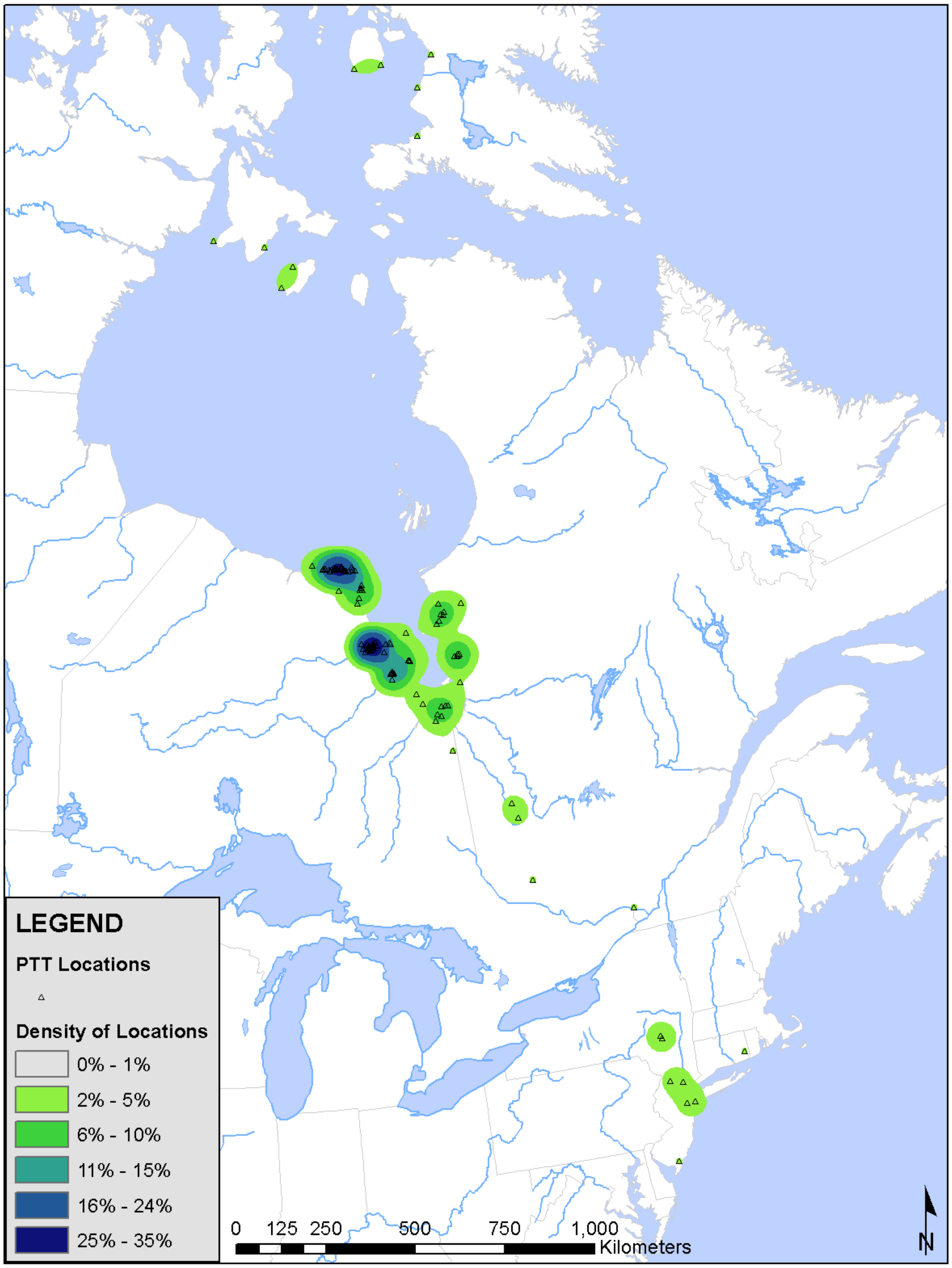


Figure 7. Locations and density of locations for PTT-marked brant during fall migration. Fall migration for each brant was defined as the period between its last known date in the Foxe Basin region and its first known date in the Atlantic Coast region.

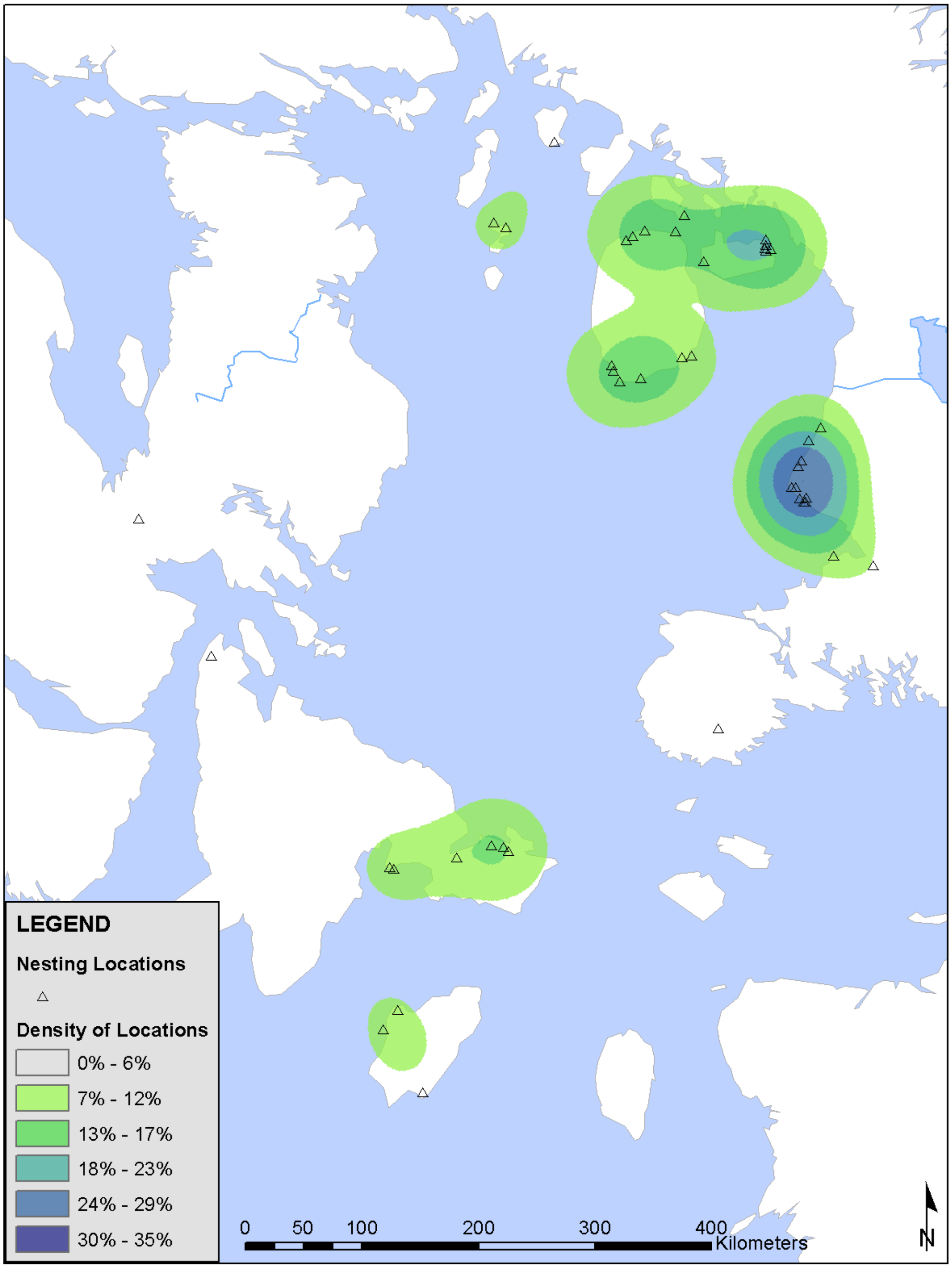


Figure 8. Nesting season locations and density of locations for VHF- and PTT-marked brant (n = 44). One brant provided a nesting season location in both years.

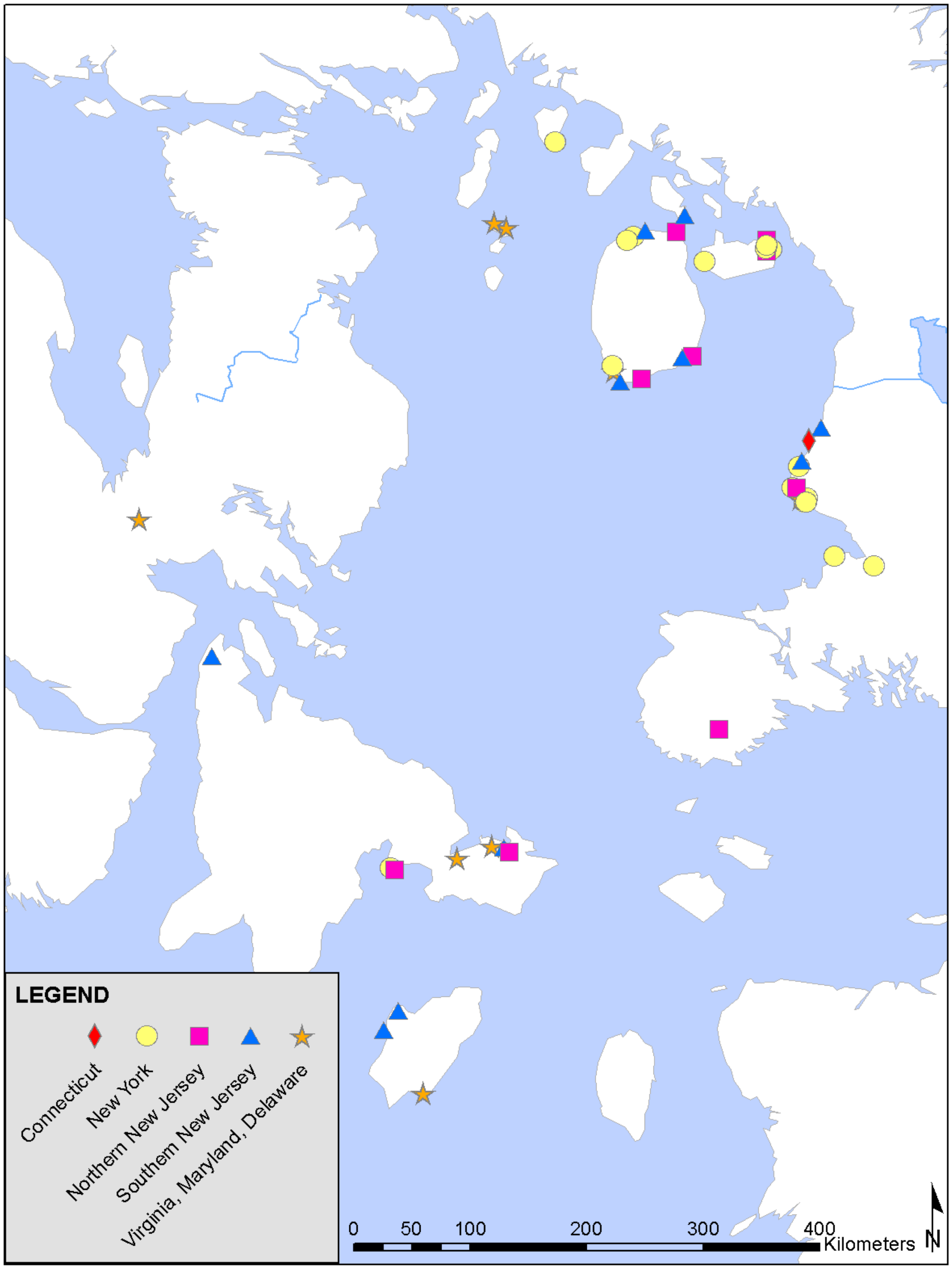


Figure 9. Nesting season locations in relation to winter capture locations within 5 Atlantic Coast sub regions. Capture locations were considered representative winter locations because we observed very few large-scale movements of our marked brant between January and March during our capture period.

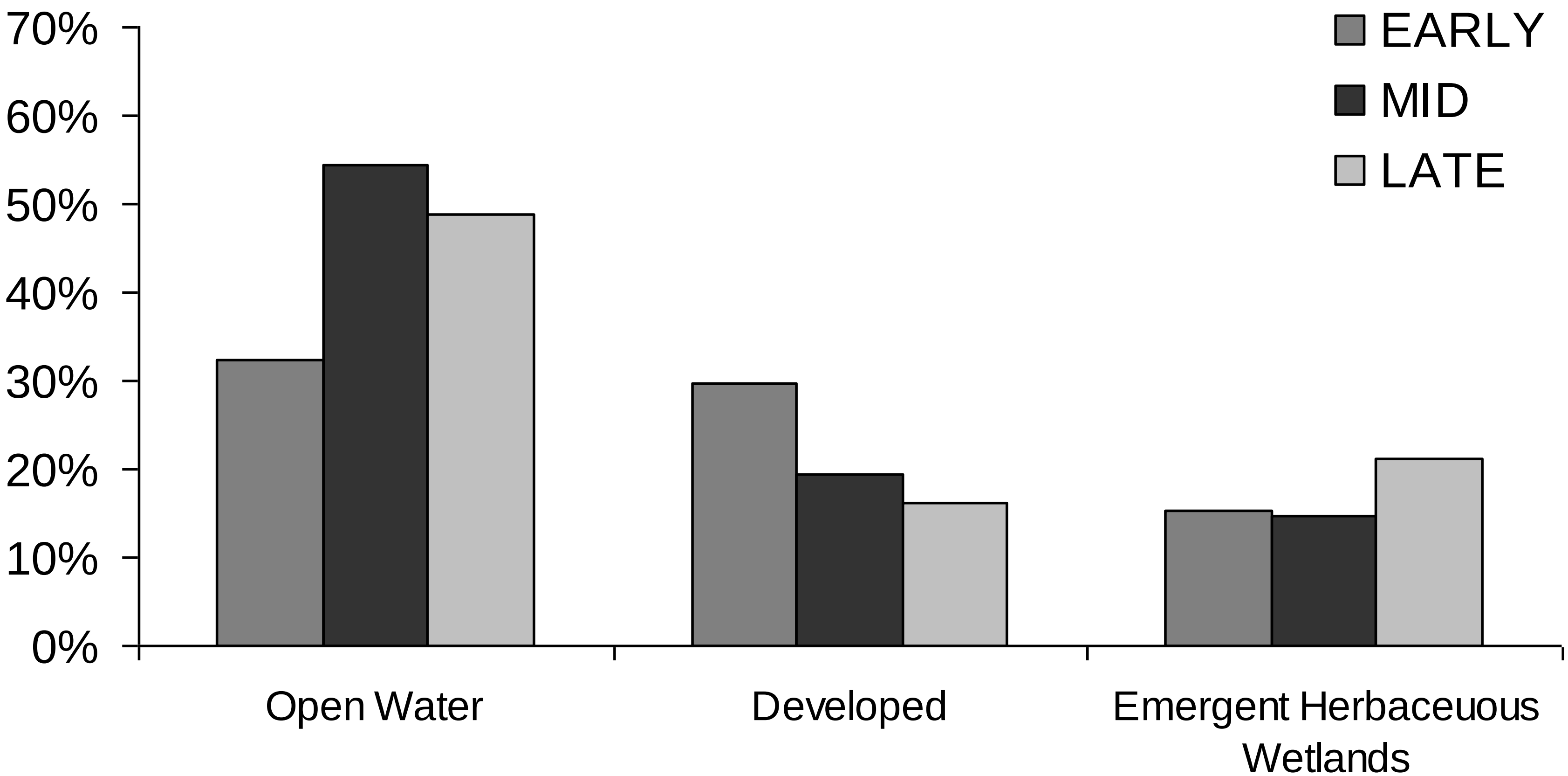
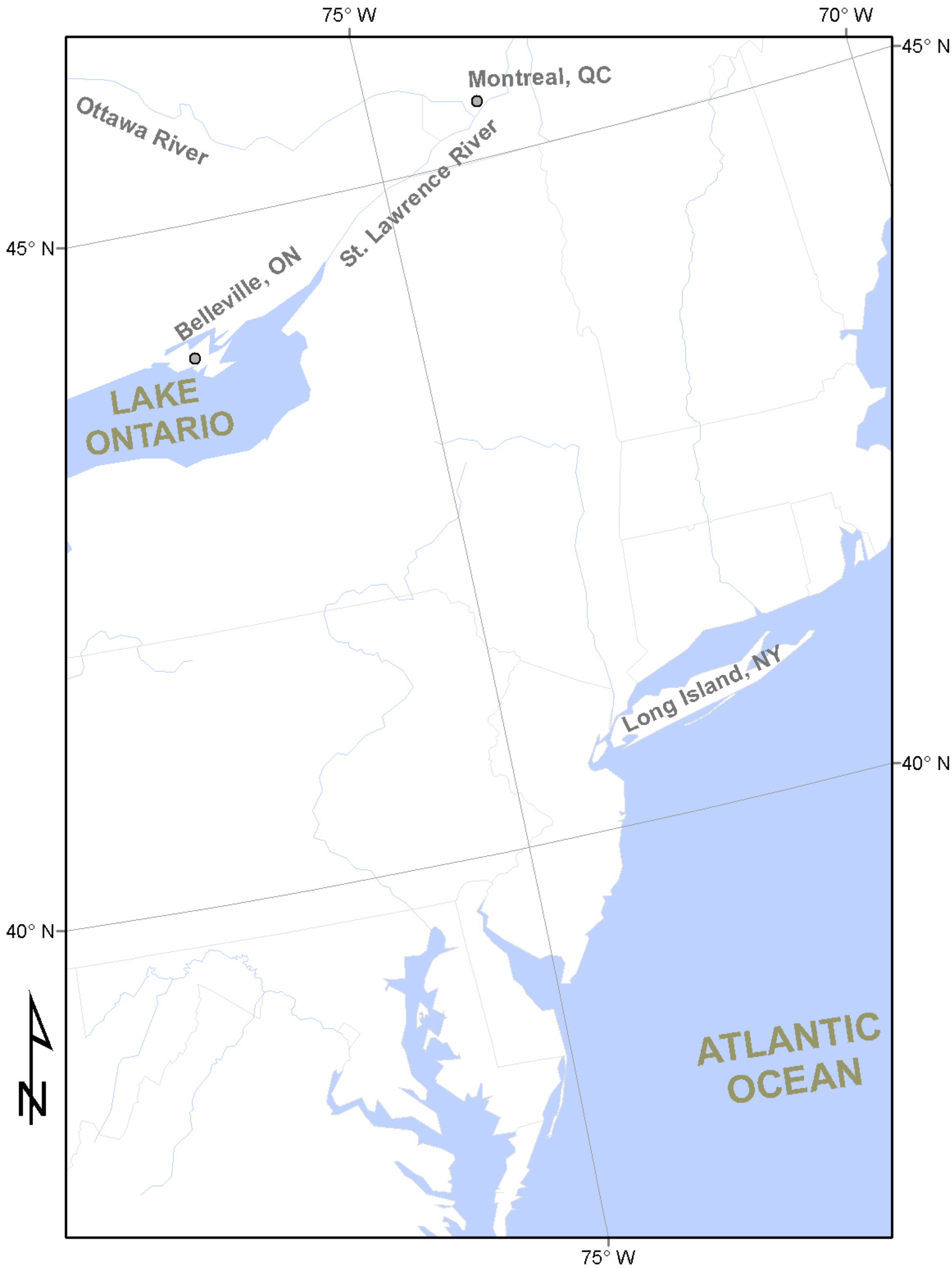


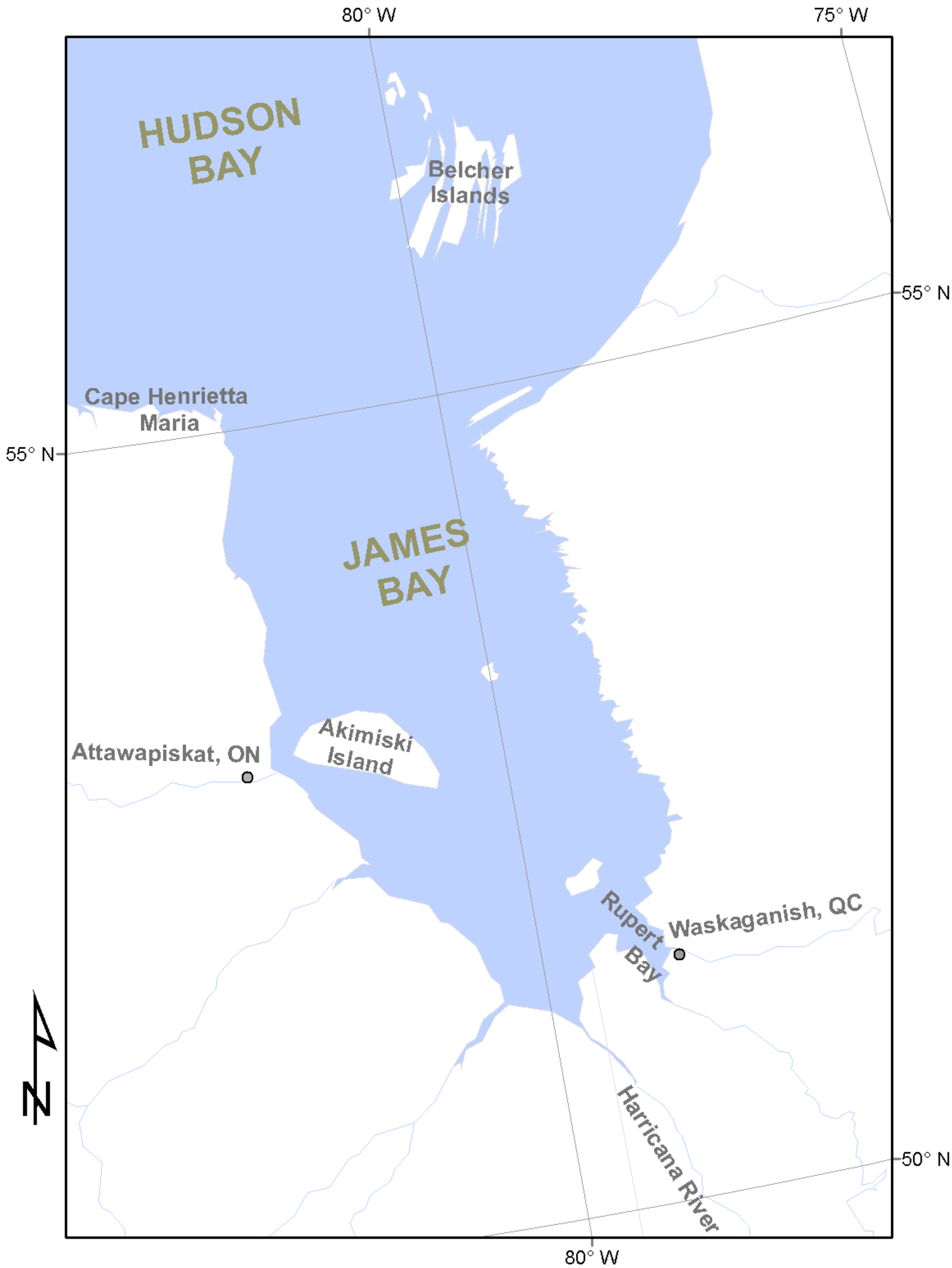
Figure 10. Summary of PTT- and VHF-marked brant locations by habitat type in the Atlantic Coast region

APPENDIX A1. NAMES OF SELECTED LOCATIONS THROUGHOUT THE RANGE OF ATLANTIC BRANT APPEARING IN THE TEXT.

APPENDIX A2. NAMES OF SELECTED LOCATIONS WITHIN THE ATLANTIC COAST REGION APPEARING IN THE TEXT.



APPENDIX A3. NAMES OF SELECTED LOCATIONS WITHIN THE JAMES BAY REGION APPEARING IN THE TEXT.



APPENDIX A4. NAMES OF SELECTED LOCATIONS WITHIN THE FOXE BASIN REGION APPEARING IN THE TEXT.