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Richard C. Cotter, R. John Hughes, Peter May, Sandy Suppa, Paulusi Novalinga, Jimmy Johannes, Larry J. Hindman, Paul I. Padding

Quebec Region

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ATLANTIC POPULATION CANADA GOOSE NESTING STUDY AND MONITORING PROGRAM IN NUNAVIK, QUEBEC, 1996–2011

Richard C. Cotter[1], R. John Hughes[2], Peter May[3], Sandy Suppa[3], Paulusi Novalinga[4], Jimmy Johannes[4], Larry J. Hindman[5], Paul I. Padding[6]

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[1] Environment Canada, Canadian Wildlife Service,
801-1550 d'Estimauville Avenue, Quebec, Canada G1J 0C3
[2] Environment Canada, Canadian Wildlife Service,
335 River Road, Ottawa, Ontario, Canada K1A 0H3
[3] Nunavik Research Centre, Makivik Corporation,
P.O. Box 179, Kuujjuaq, Quebec, Canada J0M 1C0
[4] Nunavik Hunting, Fishing, and Trapping Association,
P.O. Box 879, Kuujjuaq, Quebec, Canada J0M 1C0
[5] Maryland Department of Natural Resources,
828B Airpax Road, Suite 500, Cambridge, Maryland,
United States of America 21613
[6] Division of Migratory Bird Management, U.S. Fish and Wildlife Service,
11510 American Holly Drive, Laurel, Maryland, United States of America
20708

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Environment Canada
Inquiry Centre
10 Wellington Street, 23rd Floor
Gatineau QC K1A 0H3
Telephone: 1-800-668-6767 (in Canada only) or 819-997-2800 Fax: 819-994-1412
TTY: 819-994-0736
Email: enviroinfo@ec.gc.ca

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ABSTRACT

The size of the Atlantic Population of Canada Geese (*Branta canadensis interior*) declined from approximately 118,000 breeding pairs in 1988 to 34,000 pairs in 1995. Management agencies in Canada and the United States responded by implementing several measures, notably closing sport hunting seasons for a number of years in most Atlantic Flyway states and provinces and funding a research and monitoring program on the nesting ecology and recruitment of this goose population. This report presents the results of the research study and monitoring program that was conducted on the tundra nesting grounds in Nunavik, Quebec, specifically on a primary study area (32.8 km^2) located on the Polemond River, 8 km inland from Hudson Bay (1997–2003; n=3085 nests) and on several smaller secondary sites (most <1 km^2) distributed along the coastal lowlands of Hudson Bay (1996–2005; n=1749 nests on 7 sites) and Ungava Bay (1996–2011; n=1474 nests on 10 sites). In the late 1990s the population rebounded, with strong increases in the size of the breeding population and the density of nests on the study sites between 1996 and 2001, followed by stabilization for both variables in the following years. As a result, there was a near doubling in the number of goslings produced per km^2 (productivity index) on the primary study area, from 17.9 in 1997 to 32.0 in 2003. In most years, Canada Geese arrive on their breeding grounds in Nunavik, northern Quebec, during the first two weeks of May, a period when the snow melts and open ground appears and nest sites become available. In our study, we found that the mean temperature during this period, specifically 4–24 May, is an important factor influencing key breeding parameters. At the primary study area we found significant correlations between this temperature and clutch initiation date (negative, r=-0.94) and clutch size (positive, r=0.77) and a weak correlation (positive; r=0.69) with productivity index. Mean clutch initiation date, clutch size, hatching date, and Mayfield nesting success for the primary study area (years pooled) were 27 May, 4.54 eggs, 26 June, and 67.3%, respectively. Among the secondary sites, between 1996 and 2005, the annual mean clutch initiation date ranged from 19 May to 9 June along Hudson Bay and from 20 May to 11 June along Ungava Bay. Except for one year, the annual means of the two regions differed by 4 or fewer days. Overall mean clutch size (sites and years pooled) of each region, for this 10-year period, was similar: 4.09 eggs for Hudson Bay versus 4.03 for Ungava Bay. For both regions (1996–2005), annual mean clutch initiation date was

negatively correlated with both the annual average daily temperature for the 3-week period leading up to egg-laying (i.e., 4–24 May) (Hudson Bay: r=-0.91; Ungava Bay: r=-0.90) as well as with annual mean clutch size (Hudson Bay: r=-0.85; Ungava Bay: r=-0.90). Nesting success along the two regions varied considerably—the percentage of all nests initiated that succeeded in hatching at least one gosling was 77% for Hudson Bay versus 48% for Ungava Bay. Furthermore, nesting success was higher every year at Hudson Bay than at Ungava Bay (1996–2005). For the primary study area, the percentage of nests destroyed by predators each year ranged from 10% to 73%, but in most years (4 of 7 years) this rate was less than 25%. Each year, the Arctic Fox (*Vulpes lagopus*) was responsible for approximately three-quarters (range: 69–88%) of all nests depredated. The number of small mammals, important prey of Arctic Foxes, captured per 100 trap-nights on the primary study area ranged between 0.48 and 0.85 from 1998 to 2001 and then increased over 3-fold to 3.16 in 2002 and 2.91 in 2003. The annual gosling survival rate at approximately 4 weeks of age ranged from 42% to 63%, and the overall (years pooled) median distance moved by web-tagged goslings from their nest to where they were captured at 4–6 weeks of age during annual banding drives was 4.0 km.

RÉSUMÉ

La population de Bernaches du Canada (*Branta canadensis interior*) de l'Atlantique est passée d'environ 118 000 couples reproducteurs en 1988 à 34 000 couples en 1995. Les organismes de gestion de la faune au Canada et aux États-Unis ont réagi en mettant en œuvre diverses mesures, notamment en interdisant la chasse sportive pendant quelques années dans la plupart des États et des provinces de la voie migratoire de l'Atlantique et en finançant un programme de recherche et de surveillance de l'écologie de nidification et du recrutement de cette population de bernaches. Ce rapport présente les résultats du programme de recherche et de surveillance mené sur les aires de nidification de toundra de cette population au Nunavik (Québec), soit sur une zone d'étude principale (32,8 km^2) située sur la rivière Polemond, huit kilomètres à l'intérieur des terres de la baie d'Hudson (1997-2003; n = 3 085 nids) et sur plusieurs plus petits sites secondaires (< 1 km^2 pour la plupart) répartis le long des basses terres côtières de la baie d'Hudson (1996-2005; n = 1 749 nids sur sept sites secondaires) et de la baie d'Ungava (1996-2011; n = 1 474 nids sur 10 sites secondaires). À la fin des années 1990, la population s'était améliorée, avec de fortes croissances de l'ampleur de la population reproductrice et de la densité des nids dans les sites à l'étude entre 1996 et 2001, suivies d'une stabilisation de ces deux variables au cours des années suivantes. Ces faits ont eu comme conséquence de pratiquement doubler le nombre d'oisons produits par kilomètre carré (indice de productivité) dans la zone d'étude principale, passant de 17,9 en 1997 à 32,0 en 2003. En général, la Bernache du Canada arrive à son lieu de reproduction du Nunavik, dans le Nord du Québec, au cours des deux premières semaines de mai, durant la période de fonte des neiges, alors que des espaces ouverts apparaissent et que les sites de nidification deviennent accessibles. Dans le cadre de la présente étude, nous avons constaté que la température moyenne au cours de cette période, en particulier du 4 au 24 mai, représentait un important facteur qui a des répercussions sur les principaux paramètres de reproduction. Dans la zone d'étude principale, nous avons établi des corrélations significatives entre cette température et la date du début de la ponte (corrélation négative; r = -0,94) et la taille des couvées (corrélation positive; r = 0,77), de même qu'une faible corrélation entre cette température et l'indice de productivité (corrélation positive; r = 0,69). La date moyenne du début de la ponte, la taille moyenne des couvées, la date moyenne d'éclosion et le succès de

nidification moyen de Mayfield pour la zone d'étude principale (années regroupées) étaient respectivement les suivants : 27 mai, 4,54 œufs, 26 juin et 67,3 %. Parmi les sites secondaires, entre 1996 et 2005, la date annuelle moyenne du début de la ponte variait du 19 mai au 9 juin le long de la baie d'Hudson, et du 20 mai au 11 juin le long de la baie d'Ungava. À l'exception d'une année particulière, les moyennes annuelles des deux régions ont varié d'au plus quatre jours. Le nombre total moyen d'œufs pondus (zones et années regroupés) de chaque région, pour cette période de 10 ans, était semblable : 4,09 œufs pour la baie d'Hudson comparativement à 4,03 pour la baie d'Ungava. Pour les deux zones (1996-2005), la date moyenne annuelle du début de la ponte était corrélée négativement avec la température quotidienne moyenne annuelle de la période de trois semaines précédant la ponte des œufs, c'est-à-dire du 4 au 24 mai (baie d'Hudson : r = -0,91; baie d'Ungava : r = -0,90) et avec la taille moyenne annuelle de la couvée (baie d'Hudson : r = -0,85; baie d'Ungava : r = -0,90). Les succès de nidification ont grandement varié dans les deux régions—le pourcentage de tous les nids construits qui ont mené à l'éclosion d'au moins un oison était de 77 % pour la baie d'Hudson comparativement à 48 % pour la baie d'Ungava. De plus, chaque année, le pourcentage de réussite de nidification était plus élevé à la baie d'Hudson qu'à la baie d'Ungava de 1996 à 2005. Pour la zone d'étude principale, le pourcentage de nids détruits par les prédateurs chaque année variait de 10 % à 73 %, mais la plupart du temps (quatre des sept années), ce pourcentage était inférieur à 25 %. Chaque année, le renard arctique (*Vulpes lagopus*) était responsable d'environ les trois quarts (plage : 69 à 88 %) de tous les nids touchés. Le nombre de petits mammifères, proies importantes des renards arctiques, capturés par centaine de nuits de piégeage dans la zone d'étude principale, variait de 0,48 à 0,85 de 1998 à 2001. Ce nombre a plus que triplé pour atteindre 3,16 en 2002 et 2,91 en 2003. Le taux annuel de survie des oisons jusqu'à environ quatre semaines a varié de 42 % à 63 %, alors que la distance médiane globale (années regroupées) parcourue par les oisons marqués d'une étiquette de palmure à partir de leur nid jusqu'au lieu de leur capture après quatre à six semaines de vie au cours des cycles annuels de baguage était de 4,0 km.

ᐃᓱᒪᑖᓇᔭᐅᓯᒪᓂᑯᐃᑦ

ᐅᓄᕐᓂᖏ ᓂᕐᓖᑦ (*Branta canadensis interior*) ᐊᑦᓛᓐᑎᒃ ᓚᐊᕐᑕᓲᑦ ᐃᑭᓪᓚᕖᒥᓯᒪᓚᕐᒪᑕ 118 000ᖑᕙᓚᐅᕐᓱᑎᒃ ᒪᓐᓂᓚᐅᕐᑎᐅᖅᑲᑎᒌᑎᒍᑦ (ᐁᑉ ᐸᓈᑎᒍᑦ) 1988ᖑᑎᓪᓗᒍ 34,000ᑐᐃᓐᓇᐅᓚᕐᓱᑎᒃ ᒪᓐᓂᓚᐅᖅᑲᑎᒌᑦ (ᐁᑉ ᐸᒌᑦ) 1995ᒥ. ᐊᐅᓚᑦᓯᕗᓕᓇᔩᑦ ᑲᓇᑕᒥ ᐊᒥᐊᕆᑲᓂᓗ ᓱᒋᐊᕈᑎᖅᑲᓕᖅᑭᔪᕗᕕᓃᑦ ᑲᕗᓯᓚᕐ ᑎᓯᓂᑎᒍᑦ ᐊᒥᓱᓂᒃ, ᐱᓗᐊᕐᑐᒥ ᓂᕐᓚᓂᐊᕈᓐᓇᓂᐅᕙᑦ ᑐᓂᒃ ᐅᒃᑯᐊᓯᓂᕐᒥᒃ ᐊᕐᕿᒍᒫᕐᑐᓂᒃ ᐊᒥᓱᓂᒃ ᐊᑦᓛᓐᑎᒃ ᑯᑎᒎᕐᑐᐃᑦ ᐱᓪᓗᒋᑦ ᐊᒥᐊᕆᑫᑦ ᑲᓇᑕᐅᓪᓗ ᓄᓇᖅᑯᑎᖏ ᑎᒎᕐ ᐸᑐᑦ ᐊᓪᒪᓗ ᕿᓇᐅᔭᖅᑯᕐ ᑎᑕᐅᕙᓐᓂᖏ ᖅᑲᐅᔨᓴᖅ ᓂᓄᑦ ᑲᒪᓇᓱᖕᕕᖅᑲᐳᑎᑦ ᓴᓄᓗ ᒫᓂᓚᐅᕐ ᕕᐅᓲᓂᒃ ᓇᓗᓃᕐ ᑕᐅᓂᖅᑲᕐ ᓂᐊᓚᕐ ᑎᓗᒋᓗ ᓂᕐ ᓚᖑᕐ ᑐᓴᒫᑦ ᐅᓄᕐ ᓂᓴᖏ. ᑖᓐᓇ ᑐᓴᕐ ᑎᓯᒍᑎᒃ ᓴᖅᑭᑎᑦ ᓯᒪᑦ ᓱᖅᑯᐃᑕᐅᕗᓂᒃ ᖅᑲᐅᔨᓴᕕᖅᑲᕐ ᓂᑎᒍᑦ ᑲᒪᓇᓱᖕᕕᖅᑲᕐ ᓂᑎᒍᓗ ᓇᑎᖅ ᓇᑯᑦ ᓯᐊᓅᑦ ᑐᓂᒃ ᐅᓪᓗᓂᒃ ᒫᓂᓚᐅᖅ ᕕᐅᕗᕕᓂᖅ ᓂᒃ ᓄᓇᕕᒻᒥ, ᑯᐱᐊᒃ, ᐱᓗᐊᕐ ᑐᒥ ᖅᑲᐅᔨᓴᖅ ᕕᐅᕗᓅᖅ ᑐᕕᓂᖅ ᓂᒃ (32.8 km²) ᒥᑦ ᓯᙵᓂᒃ ᐳᓪᒪᓐ ᑰᑉ, 8 ᑭᓚᒥᑐᓂᒃ ᖅᑲᓂᖕᖕᖏᓕᓪ ᒥᒃ ᑕᓯᐅᔭᖅ ᕗᐊᒥᒃ (1997–2003; n=3085 ᐅᓪᓗᐃᑦ) ᐊᓯᖏ ᓂᓗ ᖅᑲᐅᔨᓴᖅ ᕕᐅᕗᕕᓂᖅ ᓂᒃ (most <1 km²) ᓯᓅᑯᑦ ᓯᖏᑕ ᑕᓯᐅᔭᖅ ᕗᐊᑉ (1996–2005; n=1749 ᐅᓪᓗᐃᑦ ᓯᑕᒪᐅᕗᖕᖑᕐ ᑐᕖᓂᒃ ᖅᑲᐅᔨᓴᖅ ᕕᓂᒃ) ᐅᖕᖑᕙᒥᓗ (1996–2011; n=1474 ᐅᓪᓗᐃᑦ ᖅᑲᓐᓂ ᖅᑲᐅᔨᓴᖅ ᕕᐅᕗᕕᓂᖅ ᓂᒃ). 1990 ᐃᓱᓕᒋᐊᕕᓚᕐ ᑎᓗᒋᑦ, ᐅᓄᕐ ᓂᖏ ᓂᕐᓖᑦ ᐅᑎᓚᐅᕐ ᑐᕕᓂᐅᓚᐅᓗᐊᑦ, ᐅᓄᕐ ᓯᕖᒥᕐᕗᐊᓱᑎᒃ ᒫᓂᓚᐅᖅᑲᑎᒌᕈᓐᓇᑐᑦ ᐅᓪᓗᐃᓗ ᖅᑲᐅᔨᓴᖅ ᑕᐅᕗᐃᑦ 1996ᓗ 2001ᓗ ᐊᑯᓐ ᓂᙵ ᐊᒥᓲᓂᕐ ᓴᕕᓂᐅᑦ ᓱᑎᒃ, ᐃᑯᓪᓚᔪᓐᓂᒥᑦ ᓱᑎᒃ ᐊᕐᖄᒍᓂᒃ ᑭᖕᖑᓂᖕᖏᓂᒃ. ᑌᒣᓐᓂᑯᖕᓚᓂᑦ, ᐅᓄᕐ ᓯᕖᒥᓐᓂᒪᑕ ᓂᕐ ᓚᐊᕋᖕᖑᑦ ᒪᕐᕈᕕᑲᓴᓪᓗᐊᓂᑦ ᑎᒍᑦ ᖅᑲᐅᔨᓴᖅ ᕕᐅᓚᓇᑦ ᑐᓂᒃ km² ᑕᒫᑦ (ᓂᕐ ᓚᖑᕐ ᑐᐃᑦ ᐃᑉ ᐱᒋᑦ ᓱᒋᑦ) 17.9 ᓂᑦ 1997ᒥ 32.0 ᓄᑦ 2003ᒥ. ᐃᓘᓐ ᓇᑲᓴᖏ ᐊᕐᖄᒍᐃᑦ ᐊᓂᒍᕐ ᓯᒪᓚᕐ ᑐᑦ ᐃᑉ ᐱᒋᔭᐅᓚᕐ ᒪᑕ, ᑲᓇᑕᐅᑉ ᓂᕐ ᓚᖅᑯᑎᖏ ᐃᕝᕆᐊᕐ ᑐᕕᓪ ᒥᓅᔭᓲᑦ ᓄᓇᕕᓪᒧᑦ, ᑯᐱᐊᒃ ᑕᖅᕿᑯᑦ ᓯᖕᓚᓂᑦ, ᓯᕝᕙᓪᓚᖏᓂᒃ ᐱᓇᓱᐊᕈᔫᓐᓂᒃ ᒣᒥ, ᐊᐳᑎᒃ ᐊᐅᑉ ᐸᓚᐊᓚᕐ ᑎᓗᒍ ᓄᓇᓗ ᓂᑦ ᑕᖅᑯ ᑕᓚᕐ ᒪ ᒪᓐᓂᓚᐅᕐ ᕕᓴᓪᓗ ᓲᕐᓗ ᐅᓪᓗᓚᐅᕐ ᕕᓴᖅᑲᕐ ᒪᑦ. ᖅᑲᐅᔨᓴᖅ ᑕᕝᕙᑦ ᑎᒍᑦ, ᓱᖅᑯᐃᓯᒪᓚᕐ ᑐᒍᑦ ᓂᕈᒥᓐᓂᙵ ᐱᓗᐊᕐ ᑐᒥᒃ 4-24ᒧᑦ ᒣᒥ, ᐱᓪᒪᓇᐅᒋᐊᙵ ᐃᕝᕙᓐᓂᓄᑦ. ᖅᑲᐅᔨᓴᖅ ᕕᒪᓇᑦ ᑎᓂᒃ ᖅᑲᐅᔨᓯᒪᓚᕐ ᑐᒍᑦ ᓂᕈᒥᓐᓂᙵ ᓯᓚᐅᑉ ᓱᖅᑯᓂᖅᑲᕐ ᐸᒋᐊᙵ ᐃᕝᕆᐊᓯᓂᕐ ᓄᑦ ᓲᕐᓗ ᒪᓐᓂᓚᐅᓯᓂᕐ ᓄᑦ. (ᓱᕐ ᕿᑕᐅᓂᕐ ᓗᓂᓚᒃ, r=-0.94) ᐅᓄᕐ ᓂᖕᖑᓗ ᒪᓐ ᓃᑦ ᐅᓪᓗᓂᑕᒫᑦ (ᓱᕐ ᕿᑕᐅᓂᖅᑲᕐ ᓯᐊᑐᑦ, r=0.77)

ᓱᖅᕋᑕᐅᓗᐊᒐᑎᓗ (ᓱᖅᕋᑕᐅᓂᖅᑯ ᓯᐊᑐᑦ, r=0.69) ᓂᖅ ᓕᖑᕝ ᑕᓂᑎᒍᑦ. ᒪᓐᓂᓕᐅᓯᓐᓃᑦ ᐅᓪᓗᖅᑭᑎᖕᒋ, ᖅᑯ ᓯᐅᑕᖅ ᓂᖕᒋ ᒪᓐᓃᑦ, ᐱᑭᐊᒃ ᑕᑕᖅ ᓂᖕᒋ ᐊᒻᒪᓗ ᒣᒥ ᖃᐅᔨᓴᖅᑲᐅᔪᑲᓃᑦ ᒪᓐᓂᓕᐅᖅ ᑲᓂᒃ ᑲᔪᓯᑦ ᓯᐊᓂᖅᑯ ᓂᒪᑕ ᖃᐅᔨᓴᖅ ᑲᒪᓇᐅᔪᒥᒃ (ᐊᖅ ᖀᒍᓕᒫᑦ ᑲᑎᑎᑦ ᓱᒋᑦ) 27ᖑᕆ ᓂᒪᑕ ᒣᒥ, 4.54ᖑᕝ ᓱᑎᒃ ᔩᓂᒥ 67ᐳᓯᐊᓐ ᓇᓇᔭ ᐅᔪᑲᓂᐅᑦ ᓱᑎᒃ. ᖃᐅᔨᓴᖅ ᑲᐅᒥᔪᖅ ᓂᓕ, ᐊᖅ ᖀᒍᐃᑦ 1996ᒧ 2005ᒧ ᐊᑯᓐ ᓂᖕᓂ ᓂ, ᒪᓐ ᓂᓕᐅᓯᖅᑯ ᑕᑐᑲᓂᐅᔪᑦ ᒣ 19ᒥ ᔩᓂ 9ᒧᑦ ᑎᑭᑦ ᓱᒍ ᑕᓯ ᐅᔭᖅ ᔪᐊᒥ ᐊᒻ ᒪᒧ ᒣ 20ᒥ ᔩᓂ 11ᒧᑦ ᐅᖕᒑᒥ. ᐊᑕᐅᓯᑦ ᓯᐊᖅ ᐊᖅ ᖀᒍᒃ ᐃᓚᐅᖕᖕᑑᑎᓪ ᒧᒍ, ᒪᓐ ᓂᓕᐅᖅ ᑕᓯ ᓂᖕᒋ ᑕᓯ ᐅᔭᖅ ᔪᐊᒧ ᐅᖕᒑᐅᓪ ᒧ ᐅᓪ ᒧᓂᒃ ᓯᑕᒪ ᓂᒃ ᐃᑭᓐ ᓂᓴ ᓂᒨᓐ ᓃᑦ ᐊᑦ ᔨ ᐅᖕᑑᒍᑎᓕᑲᓃᒃ. ᐃᒨᓐ ᓅᒍᑦ ᒪᓐ ᓂᓕᐊᖕᖂᑦ (ᓇᔪᓚᖕᒋ ᐅᓪ ᒧᐃᑦ ᐊᖅ ᖀᒍᔪᐃᓪ ᒧ ᑲᑎᓕᒫᖅ ᓱᒋᑦ) ᑕᒪᖕᒋ ᑕᓯ ᐅᔭᖅ ᔪᐊᒥ ᐅᖕᒑᒥᒧ, ᐊᖅ ᖀᒍᐃᑦ ᖅᑳᓪ ᐃᒧᐊᓂ, ᐊᑦ ᔨ ᑮᐸᓯᑲᓃᒃ, ᒪᓐ ᓂᓕᐅᕙᓪ ᒧᐸᓐ ᓂᑯᑦ 4.09ᓂᒃ ᑕᓯ ᐅᔭᖅ ᔪᐊᒥ, 4.03ᓂᒃ ᐅᖕᒑᒥ. ᑕᒪᖕᒋ ᓂᒃ ᑕᓯ ᐅᔭᖅ ᔪᐊᒥ ᐅᖕᒑᒥᒧ (1996ᒥ 2005ᒧᑦ), ᐊᖅ ᖀᒍᑕᒫᑦ ᒪᓐ ᓂᓕᐅᓯᕙᑦ ᑐᑲᓃᑦ ᓱᖅ ᕋᑕᐅᓂᖅ ᒧᓂᖅᑯ ᓱᑎᒃ ᐊᖅ ᖀᒍᑕᒫᑦ ᓯᓚᐅᒃ ᓂᓪ ᓚᓱ ᒧᐊᖅ ᓂᖕᖠᓃᑦ ᐱᓇᓱᐊᕈᓰᑦ ᐱᖕᖠᑦ ᐃᒧᐊᓂ ᒪᓐ ᓂᓕᐅᖅ ᐸᓕᐊᓕᖅ ᓂᒥᓄᑦ ᑎᑭᑦ ᓱᒋᑦ (ᐆᑦ ᑐᕋᐅᑎᒋᒧᒋᑦ ᒣ 4ᒥ 24ᒧᑦ) (ᑕᓯ ᐅᔭᖅ ᔪᐊᒥ, r=-0.91; ᐅᖕᒑᒥ, r=-0.90) ᐊᒻ ᒪᒨᑦ ᑕᐅᑉ ᐊᖅ ᖀᒍᑕᒫᑦ ᒪᓐ ᓂᓕᐊᖑᕚᑦ ᑐᑦ (ᑕᓯ ᐅᔭᖅ ᔪᐊᒥ, r=-0.85; ᐅᖕᒑᒥ, r=-0.90). ᒪᓐ ᓂᓕᐅᖅ ᓯᐊᓃᑦ ᑕᒪᖕᒋ ᓂ ᑕᓯ ᐅᔭᖅ ᔪᐊᒥ ᐅᖕᒑᒥᒧ ᐊᑦ ᔨ ᑮᖕᖕᕈᓇᑦ ᑑᒃ. —ᐳᓯᐊᓐ ᑕᑎᒍᑦ ᐅᓪ ᒧᓕᐊᓇᔭ ᐅᒋᐊᖕᖕᗝᓕᒫᑦ ᑲᔪᓯᑦ ᓯᐊᑐᑲᓂᐅᑦ ᓱᑎᒃ ᓂᖅ ᓕᐊᕋᖕᖑᓂᖅ ᓄᑦ ᐊᑕᐅᓯᖅ ᒥᐅᓃᑦ 77ᐳᓯᐊᓐ ᑕᑲᓃᑦ ᑕᓯ ᐅᔭᖅ ᔪᐊᒥ ᓴᓂᖕᖓ ᐅᖕᒑᒥᓕ 48ᐳᓯᐊᓐ ᑕᑲᓂᐅᑎᓪ ᒧᒋᑦ. ᓱᓕᑦ ᑕᐅᖅ, ᐅᓪ ᒧᖕᖑᐃᑦ ᓯᐊᓂᖅ ᓲᖅ ᒧ ᒪᓂᓕᐅᑦ ᓯᐊᓂᖅ ᐅᓄᖅ ᓂᓴ ᑲᓂᖅ ᐊᖅ ᖀᒍᑕᒫᑦ ᑕᓯ ᐅᔭᖅ ᔪᐊᒥᓕ ᐅᖕᒑᐅᑉ ᓴᓂᖕᖓ (1996ᒥ 2005ᒧᑦ). ᖃᐅᔨᓴᖅ ᑲᒪᓇᐅᔪᒥᒃ, ᐳᓯᐊᓐ ᑕᑎᒍᑦ ᐅᓪ ᒧᐃᑦ ᓱᒃ ᑯᐊᑎᖅ ᑕᐅᖅᑯ ᑕᓂᑲᓃᑦ ᐅᒪᔪᓄᑦ ᐊᖅ ᖀᒍᑕᒫᑦ 10ᐳᓯᐊᓐ ᑕᓂᒃ 73ᐳᓯᐊᓐ ᑕᓄᑦ, ᑭᓯᐊᓂ ᐊᒥᓲᓂᖅ ᓴᓂᒃ ᐊᖅ ᖀᒍᔪᓂᒃ (ᓯᑕᒪᑦ ᐊᖅ ᖀᒍᐃᑦ ᓯᑕᒪᐅᔪᖕᖕᑰᖅ ᑐᐃᑦ ᐃᑉ ᐱᒋᑦ ᓱᒋᑦ), ᑕᒪᓐᓇ ᐅᓄᖅ ᓂᖕᒐ ᐃᑭᓐ ᓂᓴ ᑲᓂᖅ 25ᐳᓯᐊᓐ ᑕᓄᑦ. ᐊᖅ ᖀᒍᑕᒫᑦ, ᑎᓇᓗᓐ ᓂᐊᖅ (*Vulpes lagopus*) ᐅᓪ ᒧᓕᒪᑲᓵ ᓂᒃ 3/4 ᒧᐊᖕᖏ ᓂᒃ (69-88ᐳᓯᐊᓐ ᑕᓄᑦ) ᐱᖅᑯ ᑕᑐᑲᓂᐅᓚᐅᔪᒻ ᒪᑦ. ᐅᓄᖅ ᓂᖕᒋ ᐆᒪᔪᐊᓚᕗ, ᐱᓐ ᓂᐊᓱᒍᒧᐊᖕᖕᖑᐊᑕᖕᒋ ᑎᓇᓗᓐ ᓂᐊᑦ, ᓇᒋᐊᖅ ᑕᐅᖅᑯ ᑕᑐᑦ ᓲᖅ ᒧ ᒥᑭᒋᐊᖅ ᑎᑕᐅᖅᑯ ᑕᑐᑦ ᐅᓪ ᒧᓂᒃ 100ᓂᒃ ᖃᐅᔨᓴᖅ ᑲᒪᓇᓪ ᒥ ᒥᑦ ᓯᖅᑯ ᓂᒪᑕ 0.48 ᓂᒃ 0.85 ᓄᑦ 1998ᒥ 2001ᒧᑦ ᑎᑭᑦ ᓱᒍ ᐅᓄᖅ ᓯᔩᒥᓕᖅ ᒥᓱᑎᒃ ᐱᖕᖠᑲᓪ ᒧᐊᓂᖅ 3.16ᒧᐊᓄᑦ 2002ᒥ 2.91ᒥᒧ 2003ᒥ.

ᐊᕐ ᕌᒍᑕᒫᑦ ᓂᕐ ᓚᐊᖅᑰᖅᑐᑦ ᓯᑕᒪᑦ ᐱᓇᓱᐊᕈᓲᑦ ᐃᓗᐊᓂ 42>ᓯᐊᑦ ᑕᓂᑦ 63>ᓯᐊᓐ ᑕᓅᕐ ᑕᓱᑎᑉ ᐃᓘᓐ ᓈᒍᓗ (ᐊᕐ ᕌᒍᓚᒫᑦ ᐃᑉ ᐱᕆᓱᕆᑦ) ᓅᑕᓂᕙᓂᖅᖏ ᓂᕐ ᓚᐊᕋᖅᖑᔪᒪᓚᕐ ᓱᑎᑉ ᐅᑦ ᓗᕙᓂᕐ ᒥᓂᒃ ᓯᑕᒪᑦ ᐱᖅᑯᔫᔪᕐ ᑐᑦ ᐱᓇᓱᐊᕈᓲᑦ ᐃᓗᐊᓂ 4 km ᑐᓅᑦ ᕿᑎᕐ ᓯᒥᕐ ᑐᑕᐅᒪᓂᑎᒍᑦ ᖃᐅᔨᔭᐅᒍᓐ ᓇᖅᑲ ᑕᓯᒪᔪᑦ.

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INTRODUCTION

The Canada Goose (*Branta canadensis*) is the most widely distributed goose species in North America (Mowbray et al. 2002), and for conservation purposes is divided into management populations based on breeding and wintering areas (Dickson 2000). The northernmost breeding population of medium-sized Canada Geese is the Atlantic Population (*B. c. interior*; hereafter AP Canada Geese), which was recognized by the Atlantic Flyway Council as a single population in 1983 (Wyndham and Dickson 1995). This population nests entirely in Quebec, with over 80% breeding in Nunavik, Quebec's arctic region north of 55º latitude, and the remainder nesting in the taiga and northern boreal forest as far south as 48º (Cotter et al. 1996; Rodrigue 2013). Its major wintering areas are the Delmarva Peninsula of Maryland and Delaware and portions of New York, Pennsylvania, New Jersey and Virginia (Dickson 2000; Atlantic Flyway Council 2008). This population was managed until 1996 under the principles and objectives of the *Atlantic Flyway Canada Goose Management Plan* (Atlantic Flyway Council 1989).

Up to the 1980s, the Atlantic Population (AP) of Canada Geese was the most abundant Canada Goose population in North America, with a mid-winter estimate of nearly one million birds in 1981 (Hindman and Ferrigno 1990) and an annual sport harvest in the Atlantic Flyway estimated at over 400,000 birds (Malecki and Trost 1990). In the late 1980s and early 1990s, this population experienced a dramatic decline in size due to high harvest rates and a number of breeding seasons with poor productivity. The first aerial survey of the breeding grounds on the Ungava Peninsula in Nunavik, in 1988, counted 118,000 breeding pairs (Malecki and Trost 1990), but in 1995 an aerial survey obtained a count of only 33,995 pairs (Harvey and Rodrigue 2012). This decline prompted wildlife management agencies in Canada and the United States to close sport hunting seasons throughout most of the Atlantic Flyway in 1995 and to develop an action plan specific for this population—the *Action Plan for the Atlantic Population of Canada Geese* (Atlantic Flyway Council 1996), detailing objectives and strategies for the recovery of the population, including monitoring and research needs. In 2008 this *Action Plan* was revised and updated as *A Management Plan for the Atlantic Population of Canada Geese* (Atlantic Flyway Council 2008).

A key objective of the *Action Plan* (Atlantic Flyway Council 1996) was to document recruitment parameters, such as nesting phenology, clutch size and nesting success. The *Action Plan*, therefore, recommended a multi-year study of the breeding ecology (primary study area) and the implementation of an annual monitoring program to measure breeding effort and success at key locations (secondary sites) on the Ungava Peninsula. The monitoring program was established in 1996 and was conducted every year to 2011 (total of 3223 nests), while the research study was conducted from 1997 to 2003 (3085 nests). Preliminary results of each breeding season were provided in annual reports for the Atlantic Flyway Council—1996 to 2001 by R.J. Hughes and 2002 to 2011 by R.C. Cotter (eg., Hughes 2001)—and an overview of the study up to 2004 and a scientific arcticle with key reproductive results up to 2005 have been presented in Cotter et al. (2009) and Cotter et al. (2013), respectively. The objective of this final, comprehensive report is to present, in detail, the methodology and results of the many aspects of the breeding ecology study and the nesting monitoring program from 1996 to 2011.

STUDY AREA

This study was carried out on the Ungava Peninsula, in the Nunavik area of northern Quebec (Figure 1). This tundra region lies within the Arctic Ecoclimatic Province (Canada Committee on Ecological Land Classification 1989). The highest densities of AP Canada Geese breeding pairs are found in two regions: the coastal lowlands of eastern Hudson Bay and the coastal lowlands of southwestern Ungava Bay (Malecki and Trost 1990; Harvey and Rodrigue 2012), specifically between the Inuit communities of Inukjuak and Akulivik on Hudson Bay and between Kuujjuaq and Kangirsuk on Ungava Bay. We therefore chose to locate the primary study site (research study) and the secondary sites (monitoring program) in these two regions (Figure 1; see Appendix 1 for coordinates of the study sites).

The primary study area, 32.8 km^2 in size, was situated along the Polemond River at 59º 31.5' N, 77º 36.1' W, approximately 10 km inland from the Hudson Bay coast and 60 km south of Puvirnituq (Figures 1, 2). This study area is characterized by lichen-heath

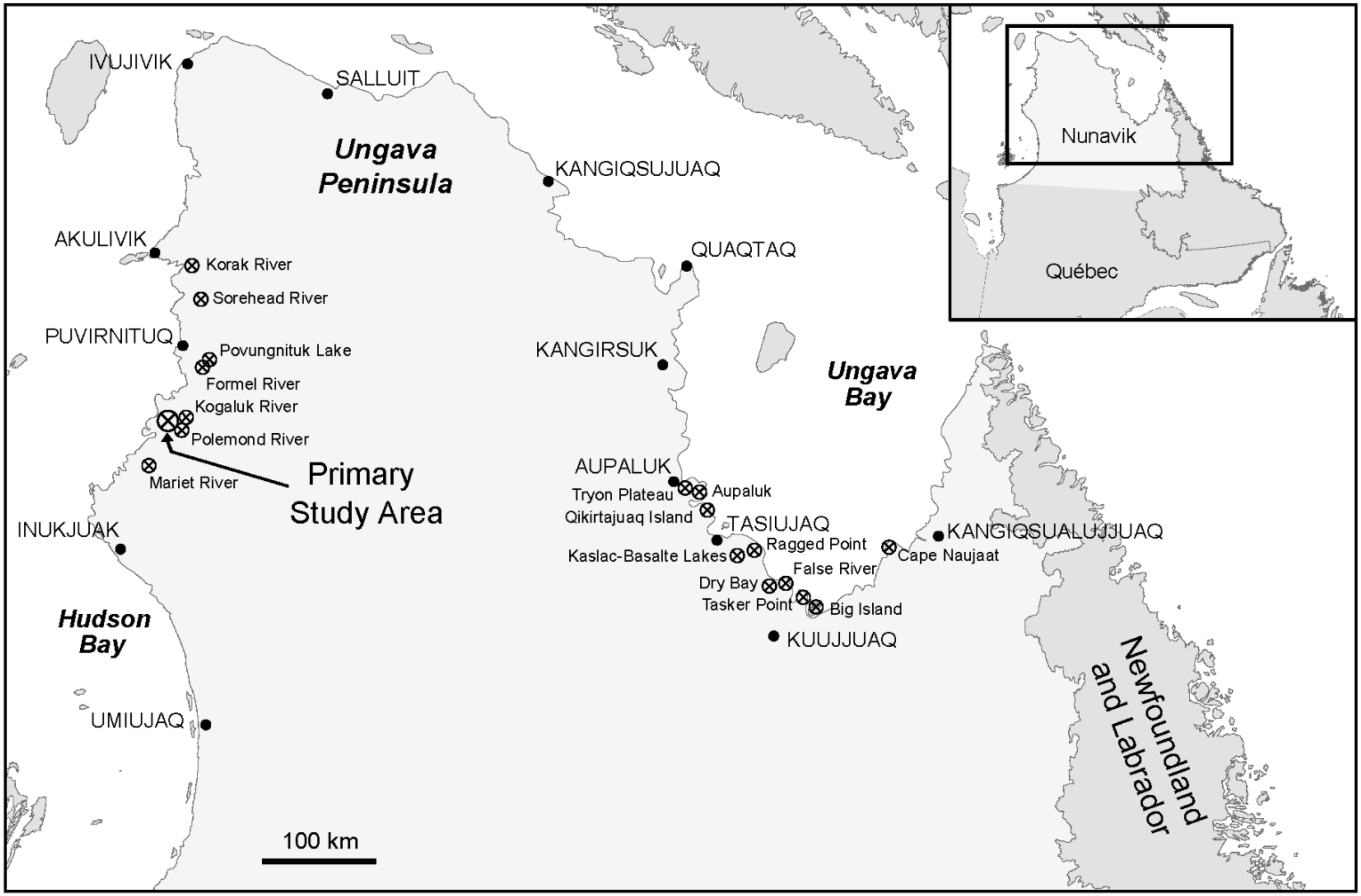

Figure 1. Location of Canada Goose primary and secondary nesting study sites along Hudson Bay and Ungava Bay in northern Quebec.

tundra (approximately 65% of total area), lakes (22%), wet sedge meadows (11%), and ponds and streams (2%) (Cadieux et al. 2005). Lichens, Dwarf Birch (*Betula glandulosa*), Mountain Cranberry (*Vaccinium vitis-idaea*), and Crowberry (*Empetrum nigrum*) are the dominant plant cover in the lichen-heath tundra, whereas wet-sedge meadows are comprised mostly of mosses, Water Sedge (*Carex aquatilis*) and Cottongrass (*Eriophorum angustifolium*). Edges of most ponds are dominated by sedges (*Carex* spp.) and Cottongrass, whereas along lakes willow (*Salix lanata*) is the dominant plant species (Cadieux et al. 2005).

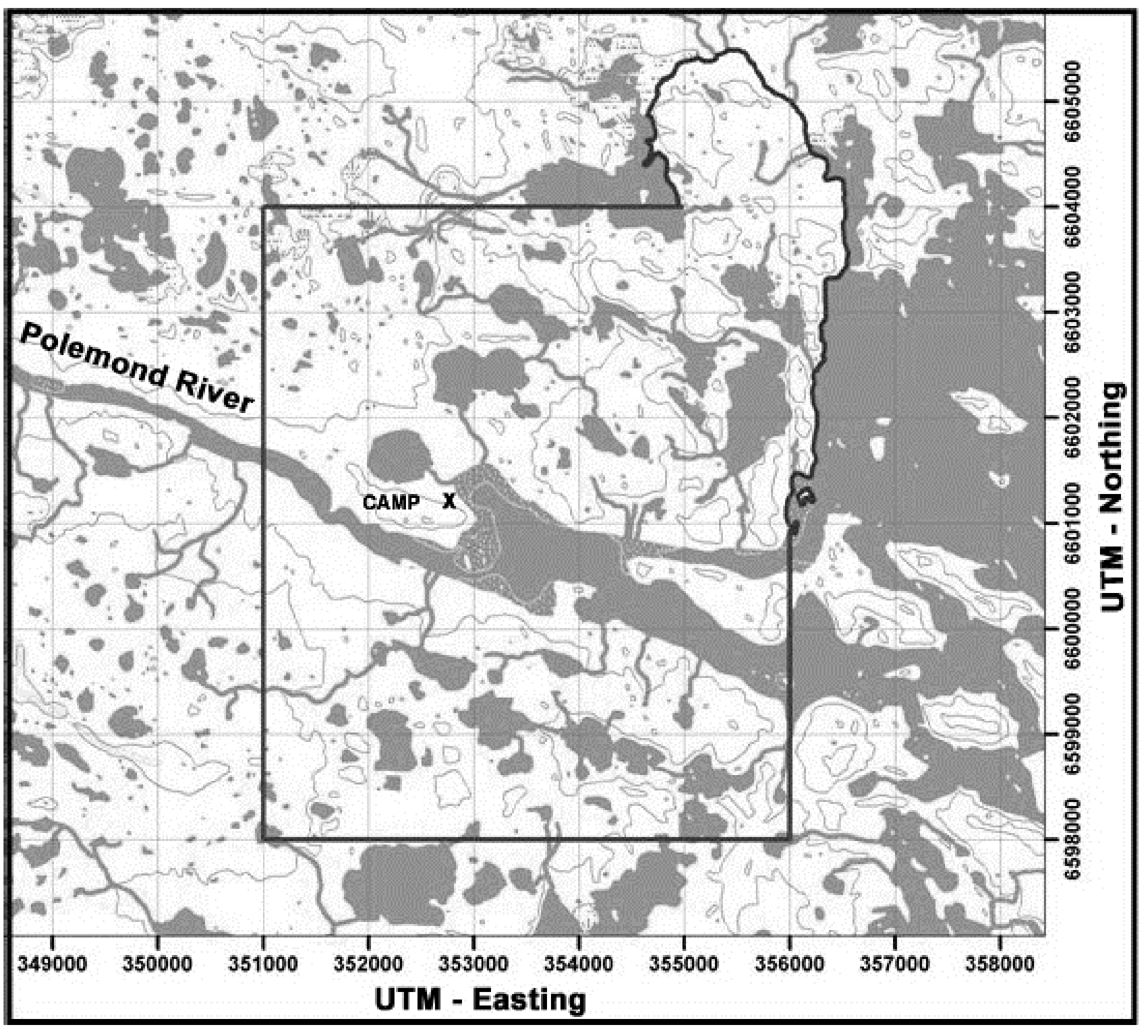

Figure 2. Map of the Canada Goose primary nesting study site in northern Quebec.

The secondary study sites were located in two stretches, each approximately 180 km long, of coastal lowlands, one along Hudson Bay and one along Ungava Bay. The distance between these two regions (coastal lowlands) is approximately 500 km. Along Hudson Bay there were seven secondary sites located between the Mariet River (59º 9' N) in the south and the Korak River (60º 46' N) in the north (Figure 1). These sites ranged in size from 0.35 km^2 to 0.64 km^2 and were surveyed from 1996 to 2005. All sites were surveyed every year except 1996, when only five sites were surveyed. Along Ungava Bay there were ten secondary sites, however, no more than six were surveyed in any one year and only five sites were surveyed in six or more years (between 1996 and 2011). With one exception, these sites were located between the Whale River (Rivière à la Baleine)—located approximately 40 km east of Kuujjuaq—in the south, and Aupaluk in the north (Figure 1). The exception was a site located farther east along Ungava Bay, about 30 km northwest of Kangiqsualujjuaq; it was surveyed in only two years and there were few nests found there. The Ungava Bay sites ranged in size between 0.25 km^2 and 2.46 km^2.

METHODS

Spring weather

At our camp in the primary study area on the Polemond River, meterological data and indices of spring phenology were recorded daily. Twice each day, once in the morning (~08:00 EST) and again in the evening (~20:00 EST), the following weather variables were recorded: current, minimum and maximum temperatures; wind direction (using a compass) and speed (in knots, using a Davis Instruments TurboMeter™); percent cloud cover (visual estimation); and precipitation (using a pluviometer). For the larger geographical region along Hudson Bay and Ungava Bay, for the months of May, June, July and August we obtained the daily temperatures (minimum and maximum) recorded at the Puvirnituq airport (Hudson Bay) and the Kuujjuaq airport (Ungava Bay), and daily precipitation amounts (snow and/or rainfall) from the Kuujjuaq airport (available online at: http://climate.weather.gc.ca/advanceSearch/searchHistoricData_e.html [use "Search by

Station Name" box]). For each day, we computed the mean daily temperature as the average of the minimum and the maximum temperatures, and for each week the mean weekly temperature was calculated as the average of the mean daily temperatures.

Breeding ecology

The following sections describe methodologies used on the primary study area, except for the section entitled "Secondary sites." Unless otherwise stated, we used analysis of variance (PROC ANOVA; SAS Institute 2004) to compare means of two or more samples, such as among years or between Hudson Bay and Ungava Bay, followed by Tukey's studentized range procedure for multiple comparisons. Annual differences in parameters with a binomial distribution, such as nesting success, were evaluated using contingency tables analyses (Likelihood ratio chi-square [G-test of independence]; Sokal and Rohlf 1981; PROC FREQ), and correlations between sets of two variables were analyzed by calculating Pearson product-moment correlation coefficients (r) (PROC CORR). The significance level was set at $\alpha<0.05$ for all statistical tests.

Nesting phenology

Nest searches began immediately upon the crew's arrival at the study area in May or as soon it was apparent that some geese had initiated nesting. Once nesting had commenced, the field crew (5 or 6 people depending on the year) began searching for nests, which consisted of members walking approximately 50 m apart and searching the study area systematically, with an emphasis given to closely searching the edges of wetlands and ponds. Depending on the weather and the amount of snow cover, 3–5 days were required to search the entire study area. Upon finding a nest, the field crew assigned it a number, and its location (Universal Transverse Mercator [UTM] coordinates) was recorded using a hand-held Global Positioning System (GPS) (Garmin; models 48 and 76). To assist with relocating nests for repeat visits, a 1-m stake was placed 25 m from each nest. During the first visit to a nest, the following information was recorded: date and time; nest status when found (laying, incubating, hatching, abandoned, destroyed, unknown); the number of eggs (and each egg numbered sequentially with a permanent marker from first to most recently laid, as determined by staining [oldest having the most staining; Raveling and Lumsden 1977]); the status of each egg (warm or cold, intact or broken, in the nest or out of the nest); the mass (nearest g), length and width (nearest 0.1 mm) of each egg; and a number of descriptive nest site variables (see details in the following section). After the initial visit, all nests were revisited approximately every 3 days until either no new eggs were found in the nest or the nest was depredated or abandoned. For new eggs, the same information was recorded as during the first visit. If no new eggs were laid, we assumed that laying was completed and we recorded the total clutch laid (i.e., clutch size [CS]) for the nest. The nest was then not revisited until mid-incubation, at which time it was then visited every 2–3 days, with the penultimate visit timed to occur with the start of hatching. The last visit occurred 1–2 days after pipping began in order to web-tag each gosling (see also section "Clutch size and nesting success"). Clutch initiation date (also known as nest initiation date) was defined as the date the first egg was laid and was calculated for each nest by subtracting a number equal to total clutch size minus one from the date on which incubation began (i.e., the date the last egg was laid). Eggs are laid at intervals of approximately 35 hours (see Mowbray et al. 2002); therefore, for large clutches (four or more eggs) an egg was not subtracted from the total clutch size. Hatch date was defined as the date on which all eggs in the nest had begun pipping (star-pip or hole-pip stage), and length of incubation was calculated by subtracting the start of incubation from the hatching date (for this variable we used only nests found during laying).

Nest site characteristics and fidelity

In addition to recording each nest's geographic location using a GPS, a number of descriptive habitat variables were measured and recorded:

- the approximate dimensions and the type of the nearest wetland (pond, stream, lake, wet meadow, or none if there was no water within 100 m)
- the shortest distance from nest to water, the vertical height of the nest above the surface of the water, and the depth of the water

- if the nest was on an island, the length and width through the approximate centroid of the island (island area was calculated as the product of its length and width), the shortest distance from the island to solid ground, and the minimum water depth between the island and solid ground
- all plant species and the average height of each within a 1-m radius
- the type of material used to construct the nest and cover the eggs

All nests were classified into two broad habitat categories based on proximity to a waterbody: dry (>10 m to a waterbody larger than 0.0021 ha [e.g., 3 m x 7 m]); and wet (≤ 10 m to a waterbody larger than 0.0021 ha). Dry habitats had two subcategories: mainland and wet meadow (areas of saturated ground, usually with numerous shallow pools with emergent vegetation). Wet habitat had three subcategories: peninsula, shoreline and island.

Each year, from 1997 to 2002, a number of females were captured on their nest and fitted with a rigid plastic neck collar. These were orange with white 4-digit alphanumeric codes (2 letters and 2 numbers). If a marked female nested in a subsequent year, the inter-annual distance was calculated (i.e., for an individual goose, the distance of its nest in year 1 to its nest in year x) as a measure for nest site fidelity.

Clutch size and nesting success

The total number of eggs laid in a nest (clutch size, CS) was calculated only for nests found during egg laying, and was determined by revisiting the nest every 2–3 days until no new eggs were found in the nest. Clutches destroyed prior to completion were excluded from calculation of CS. Beginning one or two days before the expected hatch date, each nest was visited every second day until hatch occurred, to mark goslings with individually numbered web-tags and to evaluate hatching success and record the nest’s fate. Clutch size at hatch (CSH) the number of goslings leaving per nest (GLN), and hatching success (HS = GLN/CS) were recorded for each successful nest. Nest fate categories were as follows: successful (at least one egg hatched), abandoned (clutch still intact but eggs cold), destroyed (i.e., predation; complete absence of eggs or presence of broken egg shells with membrane attached in or within 10 m of the nest), observer destroyed (one nest in 1997 and three nests in 1998), infertile, or unknown. Total nest failure occurred if all the eggs of a nest were depredated or abandoned before hatching. Both apparent nesting success, i.e., the percentage of nests initiated that hatched at least one gosling, and Mayfield nesting success (Mayfield 1961; Johnson 1979) were calculated. Nests found after they had failed were included in calculating apparent nesting success but excluded for the Mayfield method, because a nest must be under observation (i.e., exposure) for at least one day to be included in the calculations. If a nest was observed to have failed between two visits, the date of failure was assumed to be halfway between the two visits (Klett and Johnson 1982). Means and standard errors were calculated for CS, CSH, GLN, HS and nesting success; percentage of nests depredated; percentage of nests abandoned, and percentage of nests unknown or other. The standard errors (SE) of the last four parameters were based on the binomial distribution (i.e., SE = $\sqrt{(pq)/n}$, where p = the proportion of nests successful, depredated, abandoned or other/unknown; $q = 1-p$; and n = total number of nests.

Gosling survival and population productivity

Gosling survival (GSURV) from hatch to banding was calculated, for every brood for which at least one gosling was captured, as the proportion of goslings that had left the nest (status of leaving the nest was categorized as confirmed, probably left the nest, or unknown) and that were subsequently captured during banding. Goslings that were marked but were known to have died before leaving the nest were excluded. A factor that could bias GSURV occurs when no members of a brood survived, i.e., total brood loss (TBL), which is impossible to distinguish from marked broods simply not encountered during banding. An indication of annual TBL differences is obtained by comparing the proportion of marked broods (% broods recaptured) for which one or more goslings were recaptured.

An annual index of population productivity (PI; number of goslings per km^2) was calculated as follows:

PI = nest density × Mayfield nest success × GLN × GSURV

In addition to PI, we calculated an annual ratio of immatures (i.e., goslings) to adults (I:A) captured during banding drives (catches) (26 July–18 August) for Hudson Bay and Ungava Bay regions combined. The "observed" I:A is calculated once the banding program has ended in mid-August, but we "predict" the I:A in early July using a model developed by Dr. Eric Reed (Population Analyst, Canadian Wildlife Service) based on weather data from Kuujjuaq, specifically daily mean temperatures (Celsius) and snowfall (cm):

Predicted I:A=May mean temperature × 0.0869 + June total snowfall × -0.0163 + 1.4334

Gosling growth

Each year, at hatch every gosling was fitted with a uniquely numbered web-tag (size 1, National Band and Tag Co.). Marked goslings and their parents were recaptured 4-6 weeks later during annual banding drives at which time, to determine growth, a number of morphological measurements were recorded: head length, culmen length, tarsus (bone) length, tarsus (total) length, 9^{th} primary length, and mass.

<u>Growth of captive-fed goslings, 2003</u>

To examine the effect of food supply and quality on gosling growth, at hatch in 2003 one web-tagged gosling from each of 40 different nests on the primary study area was brought to the research camp (study approved by the Animal Care Committee of CWS-Quebec [project SCFQ2003-01], 30 April 2003) (see also Leafloor et al. 1998 and Lindholm et al. 1994 who used a similar protocol). The goslings were raised in captivity at the camp and were provided with ad libitum water and game bird starter (30% protein) for the first two weeks and then Purina Duck Grower (minimum 16% protein) until fledging (approximately 45–50 days of age). Each day the group of goslings were walked out to a nearby tundra meadow (with small ponds) to feed on natural vegetation. Beginning with day 1 (i.e., age 1 day old), every fourth day the following morphological measurements were recorded for each gosling: head length, culmen length, tarsus (total) length, and mass. At fledging, each gosling was fitted with a USFWS leg band, and the entire group of goslings was released approx. 20 km from camp near family groups of Canada Geese.

Secondary sites

Using nesting phenology information obtained from the primary study area or from observations provided by local Inuit, each secondary site along Hudson Bay and Ungava Bay was visited for the first time during early incubation, at which time two 2-person crews systematically ground-searched the entire site. Each nest found was assigned a unique number, its location was recorded using a GPS, a 1-m stake (painted fluorescent orange) was placed at a distance of 25 m, and each egg in the nest was numbered. The same information as that recorded for nests on the primary study area was also recorded for the secondary sites. A second visit to each site took place after hatching; to economize on travel costs (by helicopter), this visit was carried out during the banding operations (late July–mid August). During this visit, each nest was revisited and its fate was recorded. Possible nest fates were as follows: successful (i.e., presence of egg cap or membrane), abandoned (all eggs still in the nest), or predator-destroyed (absence of egg shells or presence of egg fragments with membrane attached). The area of each secondary site was calculated using the mapping software ArcView with one of two methods. For sites along Hudson Bay, ArcView was used to map each site's boundary—which remained constant across years—and then calculate the surface area. The boundaries of the Ungava Bay sites, on the other hand, were not fixed and, therefore, for each year and site we plotted the locations of all nests and ArcView calculated the surface area using the nests on the perimeter (minimum convex polygon).

Since most nests were found during incubation, we calculated clutch initiation date by first determining, for each egg in the clutch, the number of days of incubation (DAYS) at the time of the first visit. We calculated DAYS using an index of egg density (DI) and a regression of density on days, based on the principle that eggs gradually lose mass over the course of incubation, where for each egg:

$$\text{DI} = (\text{mass} / (\text{length} \times \text{width}^2)) \times 1000, \text{ and}$$

$$\text{DAYS} = (\text{DI of fresh eggs} - \text{DI of measured egg}) / \text{daily rate of change in density}$$
$$= (0.5551 - \text{DI}) / 0.003$$

Since we had neither a measure of DI for fresh eggs nor the daily rate of change in density for tundra-nesting AP Canada Geese, we used Cooper's (1978) DI value (0.5551 g/cm^3) obtained for a Canada Goose population in Manitoba and Hughes et al.'s (2000) rate of change in density (0.003 g/cm^3) for AP Canada Geese nesting in the taiga of north-central Quebec. This method was used for all sites in all years, with the exception of Hudson Bay sites in 2000 where the stage of incubation was determined by floating eggs and nest age was calculated following Walter and Rusch (1997). The density index method computes the start of incubation for individual eggs within each nest by subtracting the day of incubation (i.e., DAYS) from the date the egg was measured (presumably the date the nest was found); taking the average of the eggs in each clutch, we obtained the start of incubation date for each nest. For each nest, the start of egg laying (clutch initiation date) was obtained by subtracting a number of days equal to total eggs in the nest minus one from the date on which incubation began. As was the case for nests on the primary study area, an egg was not subtracted from the number of eggs for large clutches (≥ 4 eggs). We estimated hatch date by adding 26 days to the first day of incubation. For Hudson Bay sites in 2000, following Walter and Rusch's (1997) method for large Canada Geese in Manitoba, we first calculated the clutch age = 4.333 x stage – 2.167, where stage equals the stage of development of the yolk, and then hatch date = date found + (length of incubation – clutch age), where length of incubation is 26 days. With respect to stage of yolk development, Walter and Rusch (1997) used the six float stages described by Westerkov (1950) for Ring-necked Pheasants (*Phasianus colchicus*); in our study we grouped these six into three stages. Clutch initiation date was then calculated by subtracting (length of incubation + (clutch size – 1)) from the hatch date. (Note: an egg was not subtracted from clutch size for clutches of four or more eggs.)

For each secondary site, means (± SE) were calculated annually for clutch initiation date, hatching date, clutch size (CS; using only nests found during incubation) and nesting success. Pooling nests from all sites, an overall mean for each of these variables was also calculated for each year for both the Hudson Bay and Ungava Bay regions.

Brood surveys and movements

Ground surveys and brood movements – Primary study area

Every year after hatching had occurred, a crew of 2–3 visited a sector within the primary study area each day for a 4-hour period (07:00–11:00, 11:00–15:00, 15:00–19:00) and recorded the location and size of all individual family broods observed (broods of 10 or more goslings were considered as having goslings from more than one brood and were, therefore, excluded from analyses). These observations continued until banding commenced, at which time (for most years) goslings were 4–6 weeks of age. The distances moved by broods—specifically web-tagged goslings that were captured during the banding drives in late July–mid August—were determined by measuring the distance from the goslings' nests to their banding (catch) location.

Aerial brood surveys – Hudson Bay lowlands

From 1996 to 2001, aerial surveys of Canada Goose broods were conducted in a Bell 206L Long Ranger helicopter each year in late July–early August (see Hughes 2002). These surveys were approximately centred on Puvirnituq and covered about 200 km (north-south) of the Hudson Bay coastal lowlands, between 58º 10' N and 60º 30' N. Each year the same 10 transects, each 50–155 km long and running perpendicular from the coast, were surveyed at an approximate altitude of 100 m above sea level and speed of 100 km/hr (see Appendix 2 for transect coordinates). Eight of the transects correspond directly to, and one overlaps for the most part with, transects surveyed during the annual June breeding pair survey conducted by the Canadian Wildlife Service and the United States Fish and Wildlife Service (Harvey and Rodrigue 2005). We chose to fly the same transects as those flown during the breeding pair survey in June in order to compare brood densities with breeding pair densities each year. All observations of Canada Geese (adults without young, individual family groups [i.e., broods], and amalgamated family groups) within 200 m of either side of the aircraft were noted. Each year, the means (all transects pooled) were calculated for brood density (broods/km^2) (± standard error, SE) and brood size (± standard deviation, SD).

Aerial observations during banding program – Hudson Bay lowlands

From 1997 to 2013, approximately 50–60 hours were flown each year (approximately 1–15 August) in a Canadian Coast Guard Bell 206L Long Ranger helicopter (except in 2010 [A-Star BA, Nunavik Rotors] and in 2012 and 2013 [EC 130, Ontario Ministry of Natural Resources]) over the Hudson Bay coastal lowlands, between Inukjuak (58º 28' N) in the south and Akulivik (60º 49' N) in the north, to locate and capture moulting family groups of Canada Geese for banding (see Cotter 2014). During these flights an observer (R.J. Hughes: 1997–2001; R.C. Cotter: 2002–2013) recorded the size of individual Canada Goose broods (i.e., families not yet 'grouped-up'). For each year, the mean brood size was calculated (± SD).

Nest predation and small mammal abundance

On the study areas, the principal nest predators were Arctic Foxes (*Vulpes lagopus*), gulls (Herring Gull *Larus argentatus*, Glaucous Gull *L. hyperboreus*), and jaegers (Long-tailed Jaeger *Stercorarius longicaudus*, Parasitic Jaeger *S. parasiticus*). Upon finding a nest that was depredated, the species of predator was identified using the following criteria: fox (Arctic Fox but possibly Red Fox [*Vulpes vulpes*] also)–if a fox was observed at nest, fox tracks or fur found within 10 m of nest, or all eggs missing (no shells in or around nest); gull–if a gull was observed at nest or there were empty whole or half egg shells within 30 m of nest; jaeger–if a jaeger was observed at nest or there were punctured egg shells [or an egg with an hole in one side and the contents gone] within 5 m of nest; avian predator–if large pieces of egg shell found within 5 m of the nest; Caribou (*Rangifer tarandus*)–if the embryos are there but most of the shells seem to be gone; Black Bear (*Ursus americanus*)–eggs are crushed or broken into several small pieces (Ungava Bay only); unknown predator–if small pieces of broken shell in or within 30 m of nest. During all excursions onto the primary study area, any observations of egg and brood predators were recorded, specifically the species, number, activity, date, time and location. There is evidence from several arctic sites that small mammal populations fluctuate widely between years and that these fluctuations can have a profound effect on predation rates on goose eggs (Bêty et al. 2001; Summers et al. 1998; Wilson and Bromley 2001). To monitor small mammal populations (primarily Ungava Lemming *Dicrostonyx hudsonius*), we followed the protocol established for the Northwest Territories and Nunavut (see Carrière 1999). On the study area, four 250-metre-long transects located in two different habitat types—two transects each in lowland and upland habitats—were set up during the first year of the study (see Appendix 3 for transect coordinates). Along each transect, at a spacing of 10 m, a Museum Special snap trap was placed. In all, 100 traps were set and checked once per day between 08:00 and 10:00 for 10 days; trapped individuals were identified to species using Lupien (2002) and Desrosiers et al. (2002). The same trapping transects were used each year and they were set up in the second half of July.

RESULTS

Spring weather and nesting phenology

Inuit from Puvirnituq, the nearest village (60 km) to the Polemond River study area, begin observing Canada Geese each year in early May. This period is typically when mean weekly temperatures first exceed the freezing point of 0°C (Appendix 4). As the snow melts, open ground appears and nest sites become available for the geese, which can then initiate nesting. Each year the research crew timed their arrival to coincide with the start of egg laying, but in some years because of delayed snow melt the crew had to wait before commencing nest searches (Table 1). Snow cover at the time of the crew's arrival tended to be either very little (3 years of $\leq$ 10%) or quite considerable (3 years of $\geq$ 75%). In general, between 1996 and 2005 with respect to the timing and the rapidity of snow melt, along Hudson Bay (encompassing the primary study area and secondary sites) the years 1998, 1999 and 2001 were relatively early; 1997, 2000, 2003 and 2005 were moderate; and 1996, 2002 and 2004 were late. At the primary study area, excluding 2002 when snow melt was exceptionally late, the mean start of egg laying was relatively stable among years, ranging over an 11-day period from 21 May in 1998 to 31 May in 2000 (Table 2). There was, however, significant difference among years in the annual mean clutch initiation date ($F=900.67$, $df=6$, $P<0.01$). Pooling nests across all 7 years, for clutch initiation date the overall mean was 27 May (Table 2) whereas the median was 26 May (Figure 3).

Table 1. General winter and snow melt conditions and the timing of research crew arrival and nest searches for Canada Geese at the primary study area and at the secondary study sites along Hudson Bay and Ungava Bay in northern Quebec, 1996–2011.

Year	Average Temperature (ºC)[1] May 4–24 Puvirnituq	Average Temperature (ºC)[1] May 4–24 Kuujjuaq	Arrival at Primary Study Area Date (May)	Arrival at Primary Study Area % snow cover	Arrival at Primary Study Area General conditions on Ungava Peninsula	First Egg Laid[2] (May[3])	Nest Search Dates[4] Study Area (May[3])	Nest Search Dates[4] Hudson Bay[5] (June)	Nest Search Dates[4] Ungava Bay[5] (June)
1996	-5.4	-3.2	.[6]	.	heavy snow cover	.	.	14–16 (5)	7–11 (1)
1997	0.2	2.0	22	10	mild winter, moderate snow melt	23	24	6–8 (7)	6–9 (2)
1998	2.4	4.3	21	5	mild winter, rapid snow melt	17	22	9–11 (7)	3–6 (3)
1999	0.9	2.7	20	25	heavy snow, early rapid melt	17	21	5–8 (7)	7–10 (4)
2000	-1.4	-0.1	20	95	heavy snow, late spring melt	24	28	10–14 (7)	5–8 (4)
2001	3.5	5.6	20	5	normal snow cover & snow melt	18	21	9–13 (7)	4–9 (5)
2002	-4.6	-2.4	18	95	heavy snow, late spring melt	5	9	16–20 (7)	10–14 (6)
2003	0.0	5.5	17	75	normal snow cover & snow melt	22	24	7–12 (7)	5–11 (5)
2004	-3.7	-1.1	.	.	late snow melt	.	.	12–15 (7)	11–17 (3)
2005	0.2	3.9	.	.	normal timing of snow melt	.	.	10–13 (7)	7–8 (5)
2006	0.5	5.5	.	.	mild spring temperatures, early melt	.	.	.	6–8 (6)
2007	-5.2	-3.0	.	.	very late snow melt	.	.	.	13–15 (5)
2008	2.6	6.2	.	.	mild spring temperatures, early melt	.	.	.	9–10 (4)
2009	-5.9	-2.3	.	.	late snow melt	.	.	.	9–15 (5)
2010	-1.7	0.3	.	.	mild winter, moderate snow melt	.	.	.	8–9 (4)
2011	-4.1	-1.8	.	.	late snow melt, slow thaw	.	.	.	9 (1)

[1] Average of the mean daily temperatures (average of daily maximum and daily minimu) recorded at the Puvirnituq (Hudson Bay) and Kuujjuaq airport (Ungava Bay).
[2] Earliest clutch initiated on the primary study area.
[3] The month is June for 2002.
[4] First day of nest searches on the primary study area and the Hudson Bay and Ungava Bay secondary study sites.
[5] Number of secondary sites surveyed in parentheses.
[6] Data not available because study area was not surveyed.

Table 2. Mean annual clutch initiation date (± SE, n) of Canada Geese on the primary study area and secondary study sites (all sites pooled) along Hudson Bay and Ungava Bay in northern Quebec, 1996–2011.

	Clutch Initiation Date		
Year	Primary Study Area	Hudson Bay	Ungava Bay
1996	.	5 June (±0.5, 55)	1 June (±1.4, 12)
1997	29 May (±0.2, 127)	28 May (±0.4, 109)	24 May (±1.0, 19)
1998	21 May (±0.2, 110)	19 May (±0.4, 114)	22 May (±0.8, 55)
1999	23 May (±0.2, 199)	22 May (±0.6, 121)	24 May (±0.6, 91)
2000	31 May (±0.2, 178)	1 June (±0.3, 125)	30 May (±0.4, 72)
2001	24 May (±0.1, 322)	23 May (±0.3, 208)	20 May (±0.5, 142)
2002	11 June (±0.2, 99)	9 June (±0.5, 153)	11 June (±0.9, 137)
2003	28 May (±0.2, 284)	1 June (±0.6, 251)	20 May (±0.9, 168)
2004	.	5 June (±0.4, 176)	7 June (±1.0, 27)
2005	.	28 May (±0.5, 280)	24 May (±0.7, 82)
2006	.	.	22 May (±0.7, 47)
2007	.	.	12 June (±0.8, 48)
2008	.	.	24 May (±0.8, 65)
2009	.	.	4 June (±0.8, 55)
2010	.	.	28 May (±0.6, 55)
2011	.	.	31 May (±0.9, 24)
Long-term average[1]			
1997–2003	27 May (±0.2, 1319)	29 May (±0.3, 1081)	26 May (±0.5, 684)
Long-term average[1]			
1996–2005	.	30 May (±0.2, 1592)	27 May (±0.4, 805)
Long-term average[1]			
1996–2011	.	.	28 May (±0.3, 1099)

[1] Pooling nests from all years.

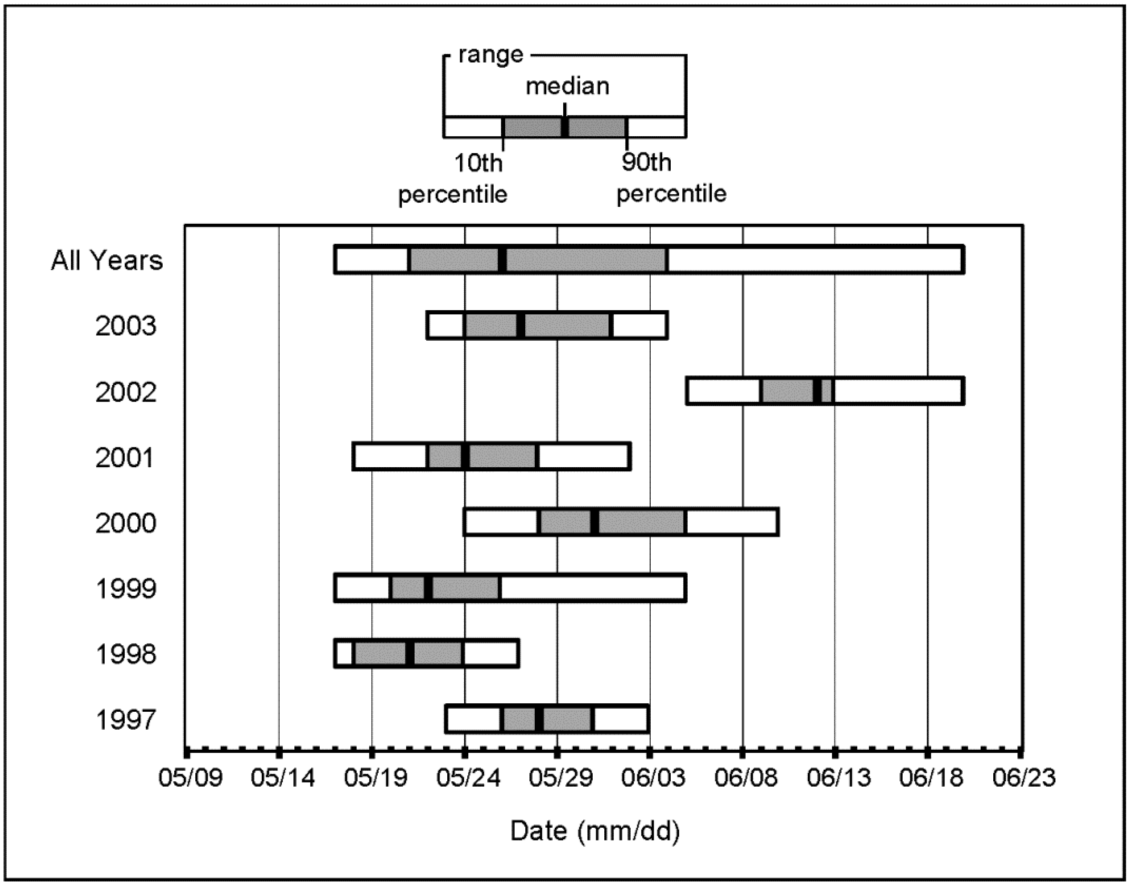

Figure 3. Phenology of the start of clutch initiation by Canada Geese at the primary study area in northern Quebec, 1997–2003.

Approximately 50% of all clutches (i.e., 25% to 75% quantiles in a frequency distribution) were initiated over 8 days, from 23 May to 30 May, and 80% (10–90% quantiles) over 15 days, from 21 May to 4 June. The earliest nest initiated was 17 May (in 1998 and 1999), 35 days earlier than the latest nest initiated, which was 20 June (in 2002). In any one year, 80% of nests were initiated over a 5–9-day period (Figure 3).

Over the larger area along Hudson Bay covered by the secondary sites, the annual mean clutch initiation dates (all nests from all sites pooled) were only 1–2 days different from the mean for the primary study area at Polemond River (Table 2), with the exception of 2003. Pooling years and sites, the overall mean clutch initiation date was 30 May for Hudson Bay (1996–2005) and 28 May for Ungava Bay (1996–2011) (Table 2). Annually (1996–2005), there were significant differences between the mean clutch initiation dates for the Hudson Bay secondary sites (pooled) and the Ungava Bay secondary sites (pooled) ($P<0.05$), with the exception of 2004 ($P=0.16$). In six of the nine years in which there was a significant difference between the two zones nest initiation was earlier along Ungava Bay (Table 2). Along both Hudson Bay and Ungava Bay (secondary sites pooled), there was a significant difference among years in the annual mean clutch initiation date (Hudson Bay: $F=14.15$, df=9, $P<0.01$; Ungava Bay: $F=86.58$, df=15, $P<0.01$). The annual mean clutch initiation dates of individual secondary sites along Hudson Bay varied by 5–15 days; in 6 of 10 years the difference was ≤ 6 days (Appendix 5). In 7 of 10 years (1996–2005), mean clutch initiation dates of secondary sites varied by fewer days among the Ungava Bay (Appendix 6) sites as compared with Hudson Bay sites. The long-term average of individual sites ranged between 26 May and 31 May for all sites along Hudson Bay and for 7 of 10 sites along Ungava Bay.

For the period 1996–2005, annual mean clutch initiation date was negatively correlated with the mean of the average daily temperatures (i.e., average of the daily minimum and maximum temperatures) at both Hudson Bay and Ungava Bay (temperatures recorded at Puvirnituq and Kuujjuaq airports, respectively) for the 3-week period leading up to egg laying (4–24 May; Table 1): primary study area ($r=-0.94$, $P<0.01$; 1997–2003 only), Hudson Bay secondary sites ($r=-0.91$, $P<0.01$) (Figure 4), and Ungava Bay secondary sites ($r=-0.90$, $P<0.01$). With this mean temperature (4–24 May), the following model can be used to calculate a predicted mean clutch initiation date at the onset of nesting: for Hudson Bay, clutch initiation date=-2.1043×temperature+27.9376, and for Ungava Bay, clutch initiation date=-2.1194×temperature+31.2453 (see Appendix 7). Including 2006–2011 for Ungava Bay sites, the correlation between the two variables is relatively unchanged ($r=-0.88$, n=16 years) (Figure 5).

The overall mean and median dates of hatching on the primary study area, all years combined, were respectively 26 June (Table 3) and 25 June. Following the same pattern as observed for the initiation of egg laying and incubation, we observed among years a considerable range in hatch dates, from as early as 15 June in 1998 to as late as 19 July in 2002. These two years also had the earliest and latest median dates, 19 June and 10 July, respectively. Again, if we exclude the year 2002, the median hatch dates were relatively uniform among years, with 12 days between the earliest (19 June) and the latest (30 June).

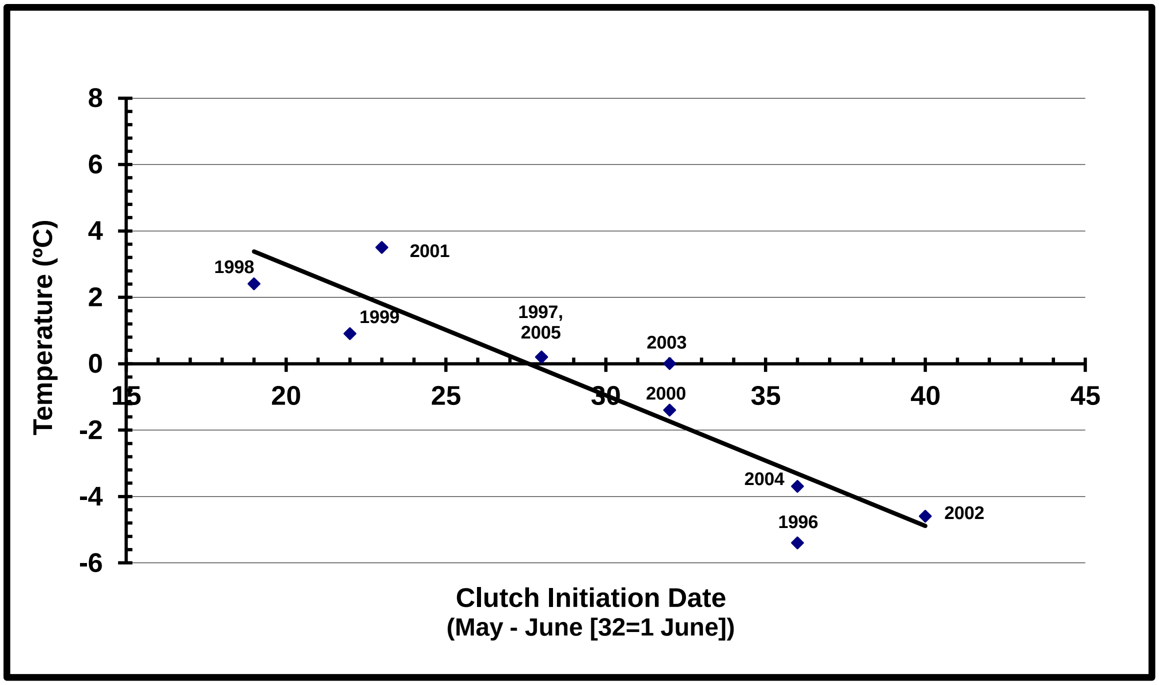

Figure 4. Regression of annual mean temperature for 4–24 May (Puvirnituq Airport) on date of start of clutch initiation at Hudson Bay secondary sites, 1996–2005.

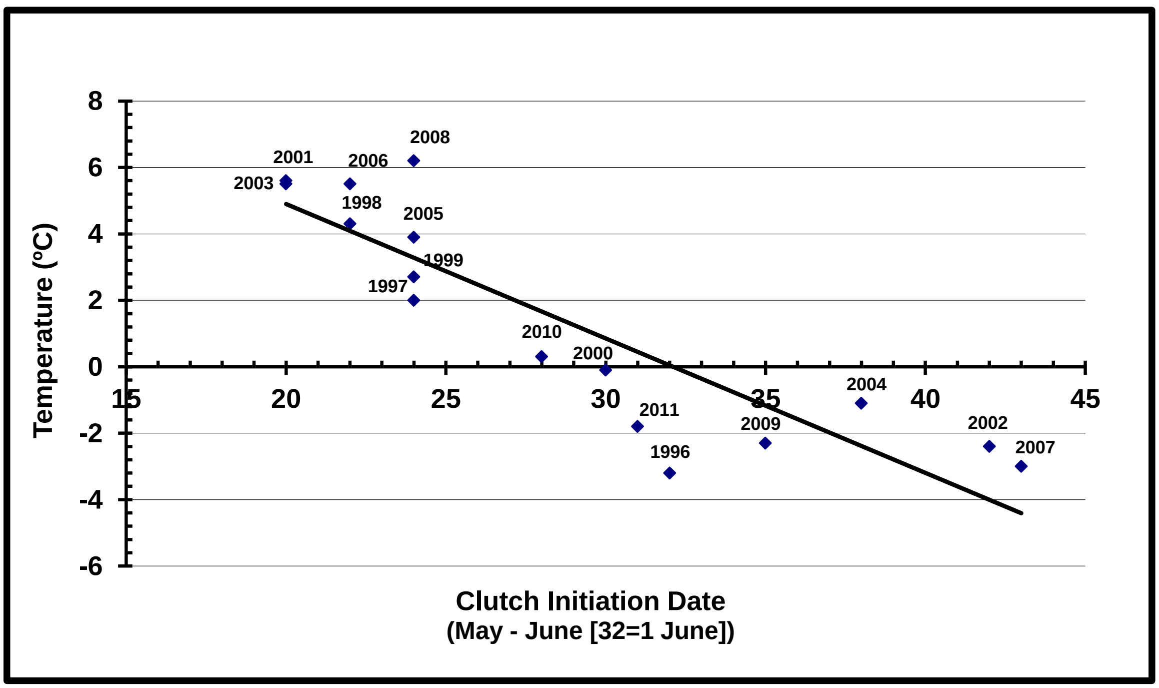

Figure 5. Regression of annual mean temperature for 4–24 May (Kuujjuaq Airport) on date of start of clutch initiation at Ungava Bay secondary sites, 1996–2011.

Table 3. Mean annual hatching date (± SE, n) of Canada Geese on the primary study area and secondary study sites (all sites pooled) along Hudson Bay and Ungava Bay in northern Quebec, 1996–2011.

	Hatching Date		
Year	Primary Study Area	Hudson Bay	Ungava Bay
1996	.	4 July (±0.5, 55)	29 June (±1.3, 12)
1997	29 June (±0.2, 220)	27 June (±0.4, 109)	23 June (±1.0, 19)
1998	20 June (±0.1, 293)	19 June (±0.4, 114)	21 June (±0.7, 55)
1999	22 June (±0.2, 245)	21 June (±0.6, 121)	23 June (±0.6, 91)
2000	30 June (±0.3, 75)	1 July (±0.2, 125)	29 June (±0.4, 72)
2001	24 June (±0.1, 505)	22 June (±0.3, 208)	19 June (±0.5, 142)
2002	10 July (±0.2, 170)	8 July (±0.5, 153)	10 July (±0.9, 137)
2003	27 June (±0.1, 475)	1 July (±0.6, 251)	19 June (±0.9, 168)
2004	.	4 July (±0.4, 176)	6 July (±0.9, 27)
2005	.	27 June (±0.5, 280)	23 June (±0.7, 82)
2006	.	.	20 June (±0.7, 47)
2007	.	.	11 July (±0.9, 48)
2008	.	.	23 June (±0.7, 65)
2009	.	.	3 July (±0.8, 55)
2010	.	.	27 June (±0.6, 55)
2011	.	.	28 June (±0.8, 24)
Long-term average [1]			
1997–2003	26 June (±0.1, 1983)	27 June (±0.3, 1081)	25 June (±0.4, 684)
Long-term average [1]			
1996–2005	.	28 June (±0.2, 1592)	25 June (±0.4, 805)
Long-term average [1]			
1996–2011	.	.	26 June (±0.3, 1099)

[1] Pooling nests from all years.

The annual mean hatching dates at the primary study area ranged between 20 June and 10 July. Except for 2003, the annual mean hatching dates for the primary study area were within 1 or 2 days of the overall mean for the Hudson Bay secondary sites (Table 3). Along both Hudson Bay and Ungava Bay, in most years the difference among the secondary sites in the mean hatching date varied by 8 or fewer days (Appendices 8 and 9).

At the primary study area, both the median and mean length of incubation for 6 of the 7 years of the study was 26 days. The exception was 2003, the last year of the study. Median length that year was 25 days, one day shorter than in other years. Mean length of incubation that year was 25.49 days (±0.08 [SE], n=213), slightly less than one full day shorter than in 2000, when the mean length of incubation was the longest, at 26.32 days (±0.17, n=44). Annually, the mean interval between the start of egg laying and hatching (eggs pipping) for the primary study area and Hudson Bay and Ungava Bay (all nests pooled from secondary sites) ranged from 28 to 31 days.

Reproduction

Nest density

Over the duration of this study, 6308 Canada Goose nests were found: 3085 on the primary study area (1997–2003), 1749 on Hudson Bay secondary sites (1996–2005), and 1474 on Ungava Bay secondary sites (1996–2011) (see Appendices 10 and 11 for maps showing locations of all nests on the primary study area and on Hudson Bay secondary sites, respectively).

At the primary study area (32.8 km^2), the density of nests increased from 8.9 nests/km^2 in the first year of the study (1997) to a high of 20.6 nests/km^2 in 2003 (Table 4), a 131% increase. Nest densities on the smaller secondary sites also increased over the duration of the study and, with a few exceptions, in any given year the densities of individual sites were considerably greater than the density on the primary study area (Appendices 12 and 13).

Table 4. Annual nest density and number of nests found on the primary study area and secondary study sites (all sites pooled) along Hudson Bay and Ungava Bay in northern Quebec, 1996–2011.

	Nest Density, n/km^2 (n nests found, number of sites surveyed)		
Year	Primary Study Area[1]	Hudson Bay[2]	Ungava Bay[2]
1996	.	25.5 (58, 5)	3.5 (16, 1)
1997	8.9 (292)	37.7 (123, 7)	14.2 (28, 2)
1998	10.6 (348)	38.7 (127, 7)	21.2 (61, 3)
1999	12.9 (423)	40.2 (130, 7)	67.1 (113, 4)
2000	11.7 (383)	49.2 (159, 7)	38.4 (80, 4)
2001	19.5 (639)	71.1 (228, 7)	40.7 (181, 5)
2002	9.9 (325)	51.2 (167, 7)	19.4 (185, 6)
2003	20.6 (675)	83.4 (273, 7)	19.1 (225, 5)
2004	.	56.4 (187, 7)	24.5 (59, 3)
2005	.	88.9 (297, 7)	43.3 (116, 5)
2006	.	.	34.1 (126, 6)
2007	.	.	32.6 (64, 5)
2008	.	.	25.4 (75, 4)
2009	.	.	33.7 (62, 5)
2010	.	.	27.0 (58, 4)
2011	.	.	34.6 (25, 1)

[1] Annual nest density = *n* nests found divided by area (32.8 km^2)
[2] Annual nest density = the average of the individual site densities (*see* Appendices 12 and 13)

The number of breeding pairs on the Ungava Peninsula increased from 51,466 pairs in 1996 to 175,679 in 2005 (Harvey and Rodrigue 2012). Between 1997 and 2001, both the number of breeding pairs on the Ungava Peninsula and the density of nests on the primary study area increased considerably (88% and 119%, respectively) and the correlation between the two was high (r =0.87, P=0.05). In 2002, however, the number of nests declined even though the number of breeding pairs continued to grow. Snowmelt was very late in 2002, resulting in a mean clutch initiation date of 11 June, approximately two weeks later than the long-term average. For many pairs it was too late, and a large proportion of the breeding population did not attempt to nest. Between 2002 and 2007, the size of the breeding population on the Ungava Peninsula stabilized, varying less than 12% from year to year (Harvey and Rodrigue 2012). Nest density had also stabilized; in 2003, the last year on the primary study area, it was only 6% higher than in 2001, and in 2005, the last year for the Hudson Bay secondary sites, nest density there was 25% higher than in 2001 (Table 4). Except in 2002 and 2004, when snow melt and nest initiation were late, the mean nest density for the Hudson Bay secondary sites tracked the trend in the number of breeding pairs on the Ungava Peninsula (Harvey and Rodrigue 2012) (Figure 6).

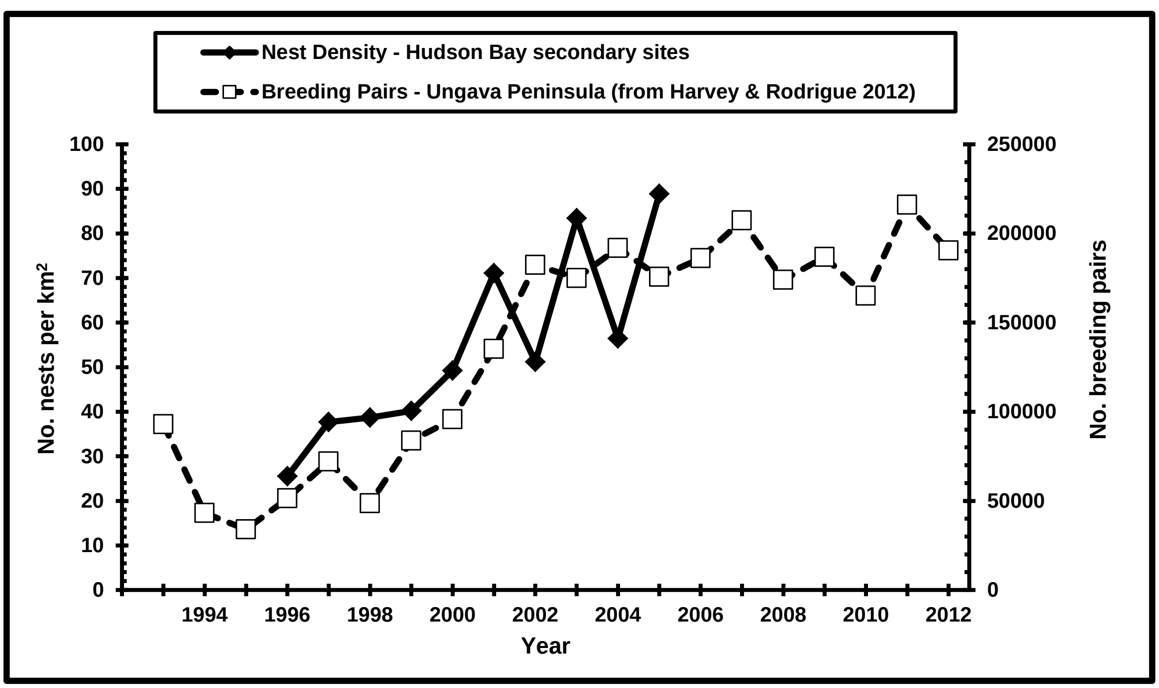

Figure 6. Atlantic Population Canada Goose nest density on Hudson Bay secondary sites and total number of breeding pairs on the Ungava Peninsula, northern Quebec, 1993–2012.

Nest site characteristics and fidelity

Pooling all years from 1997 to 2003, wet habitat (i.e., peninsula, shoreline or island) was the most common habitat type supporting Canada Goose nests: 67% (2073 of 3085 nests) of all nests at the primary study area, 85% (1026 of 1207 nests) at the Hudson Bay secondary sites, and 60% (429 of 716 nests) at the Ungava Bay secondary sites (Table 5). It should be noted that habitat type was not recorded for 157 of 873 nests at Ungava Bay. Within each of these three regions, approximately half to three quarters (46-83%) of all nests were no farther than 10 m from a body of water (i.e., shoreline), approximately one quarter (15–33%) of nests were in dry habitats (i.e., mainland or wet meadow), about 1% were on peninsulas, and less than 10% were on islands (Table 5).

Table 5. Percentage (number of nests in parentheses) of Canada Goose nests found per habitat type at the primary study area and at the secondary study sites (nests from all sites and years pooled) along Hudson Bay and Ungava Bay in northern Quebec, 1997–2003.

	Hudson Bay			Ungava Bay
Habitat type	Primary Study Area	Secondary Sites	Pooled	Secondary Sites
Mainland	12.1	7.0	10.6	23.5
	(373)	(84)	(457)	(205)
Wet meadow	20.6	7.6	16.9	9.4
	(635)	(92)	(728)	(82)
Peninsula	1.3	0.7	1.2	0.5
	(41)	(9)	(50)	(4)
Shoreline	56.5	83.3	64.0	45.9
	(1742)	(1005)	(2747)	(401)
Island	9.4	1.0	7.0	2.7
	(290)	(12)	(302)	(24)
Unknown	0.1	0.4	0.2	18.0
	(4)	(5)	(9)	(157)
TOTAL	100.0	100.0	100.0	100.0
	(3085)	(1207)	(4292)	(873)

Within each region, between 77% and 93% of all shoreline nests were found adjacent to either a pond or a lake, while 18% or less were adjacent to a stream or river (Appendix 14). Of nests located in mainland habitat (i.e., >10 m from a waterbody), 13-25% were not associated with either a hummock or a pool, while 4–8% were associated with a hummock, 14–39% were near a pool (i.e., a waterbody ≤ $21m^2$ in size), and 35-57% were classified as associated with a waterbody (pond, lake, stream, lake) >10 m from the nest. Of nests located in wet meadows, the majority (86–89%) were on hummocks (Appendix 14). On the primary study area in 2001, Cadieux et al. (2005) found the Canada Goose use of pond margins in lichen-heath tundra did not change throughout the summer and was very low, whereas the use of wet sedge meadows was much higher, with a clear peak on 23 June, which coincided with peak hatch of goslings in 2001 (Table 3).

Pooling nests from all years across all habitat types, the mean distance of nests to water was 7.4 m at the primary study area, 4.1 m at the Hudson Bay secondary sites, and 8.2 m at the Ungava Bay secondary sites (Appendix 15). Other descriptive nest variables are presented in Appendix 15. At all three nesting zones, the most common plant providing nest cover was *Betula glandulosa*; this shrub (Dwarf Birch) was ranked first (i.e., providing the most cover) at 54% of all nests at the primary study area (all years and habitat types pooled), 38% of nests at the Hudson Bay secondary sites, and 28% of nests at the Ungava Bay secondary sites (Appendix 16). This shrub is common and is widely distributed in the lowlands along Hudson and Ungava bays (pers. obs.), and its predominance at Canada Goose nests is probably directly correlated with its availability. Cadieux (2002: 88–91) found that on the primary study area, this shrub represented, of the total percent cover (per habitat type), 0.5% in wet sedge meadows, 15.3% in dry lichen-shrub habitat, and 1.7% in riparian (specifically along streams) habitat. In dry habitat this plant was over twice as common (% cover) as the next two most common vascular plants: *Empetrum nigrum* (6.5%) and *Vaccinium vitis-idaea* (6.3%). In wet sedge meadows, Cadieux (2002) reported sedges (*Carex aquatilis*, 11.7% and *C. rariflora*, 7.1%) and Cottongrass (*Eriophorum angustifolium*, 8.9%) as the most common species. At Canada Goose nests, after *Betula glandulosa* the next most common plants were *Empetrum nigrum* (Crowberry) at the primary study area, *Graminae* spp. (grasses) at the Hudson Bay secondary sites, and *Salix* spp. (willow) and *Carex* spp. (sedge) at the Ungava Bay secondary sites (Appendix 16). At the primary study area, Canada Goose nests with *Betula glandulosa* as the dominant cover were most often found with *Empetrum nigrum* and *Ledum decumbens* (Labrador Tea).

Of neck-collared female Canada geese, 46 were observed in a subsequent year (19 in 2 or 3 subsequent years) (Appendix 17) and, as a meaasure of nest site fidelity, the mean internest distance (i.e., for an individual goose the distance of a nest in year 1 to its nest in year x) was 124 m (SD=211, n=68). This distance ranged from 3 m to 1,359 m, and the median was 69 m. There was no difference between females that nested successfully on the study area the year before and those that were not successful (F=0.14, df=1, P=0.71).

Egg size, clutch size, and nesting success

Overall (years and primary and secondary sites pooled; 1996–2005), eggs had a mean length of 83.4 mm (± 0.03, n=18,992 eggs), width of 56.3 mm (± 0.01, n=18,992 eggs), and mass of 140.0 g (± 0.09, n=18,992 eggs) (Note: eggs where 95 g > mass > 185 g were considered outliers and therefore excluded). For the Hudson Bay region (i.e., pooling the primary and secondary sites), the mean length, width, and mass were 83.2 mm (± 0.03, n=15,711 eggs), 56.1 mm (± 0.01, n=15,711 eggs), and 139.3 g (± 0.10, n=15,711 eggs), respectively, and for Ungava Bay the measurements were 84.2 mm (± 0.06, n=3281 eggs), 56.9 mm (± 0.03, n=3281 eggs), and 143.8 g (± 0.25, n=3281 eggs), respectively.

For the primary study area, mean annual clutch size varied from a low of 3.6 eggs in 2002 to a high of 5.3 eggs in 1998 (Table 6). Median clutch size was 5 eggs in all years except 2000 and 2002, when it was 4 eggs. There were significant differences among years in total clutch laid (F=25.13, df=6, P<0.001). Pooling all years, mean total clutch laid (CS), clutch size at hatch (CSH), and goslings leaving the nest (GLN) were 4.5 eggs, 4.1 eggs and 3.7 goslings, respectively (the latter two variables are for successful nests only; Table 7). The overall mean for GLN was 19.4% smaller than the overall mean for CS, and this difference provides an indication of egg loss during incubation and gosling loss during hatching. This difference (loss) ranged from 16.0% in 2001 to 26.4% in 2000. Hatching success (HS = GLN/CS) of clutches, across years, was 79.9% (±0.7 [SE], n=923), and ranged between 72% in 2002 and 88% in 1997. There were significant year effects for CSH (F=51.91, df=6, P<0.001), GLN (F=40.50, df=6, P<0.001), and HS (F=4.87, df=6, P<0.001).

Table 6. Mean annual clutch size (± SE, n) of Canada Goose nests on the primary study area and secondary study sites (all sites pooled) along Hudson Bay and Ungava Bay in northern Quebec, 1996–2011.

	Clutch Size		
Year	Primary Study Area	Hudson Bay	Ungava Bay
1996	.	3.53 (±0.17, 55)	3.89 (±0.39, 9)
1997	4.98 (±0.09, 113)	4.55 (±0.10, 108)	4.36 (±0.30, 22)
1998	5.29 (±0.10, 102)	4.66 (±0.10, 121)	4.22 (±0.20, 55)
1999	4.65 (±0.07, 162)	4.15 (±0.11, 120)	4.23 (±0.13, 91)
2000	4.05 (±0.11, 111)	3.95 (±0.10, 128)	3.69 (±0.15, 67)
2001	4.49 (±0.07, 322)	4.52 (±0.08, 208)	4.07 (±0.11, 142)
2002	3.63 (±0.12, 73)	3.21 (±0.08, 141)	3.47 (±0.10, 136)
2003	4.52 (±0.06, 248	4.25 (±0.07, 251)	4.34 (±0.10, 187)
2004	.	3.11 (±0.07, 176)	3.42 (±0.23, 23)
2005	.	4.38 (±0.07, 280)	4.31 (±0.15, 81)
2006	.	.	4.09 (±0.14, 91)
2007	.	.	3.27 (±0.15, 52)
2008	.	.	4.48 (±0.18, 65)
2009	.	.	3.53 (±0.15, 51)
2010	.	.	3.87 (±0.17, 55)
2011	.	.	3.40 (±0.18, 20)
Long-term average[1]			
1997–2003	4.54 (±0.03, 1131)	4.20 (±0.04, 1077)	4.03 (±0.05, 700)
Long-term average[1]			
1996–2005	.	4.09 (±0.03, 1588)	4.03 (±0.05, 823)
Long-term average[1]			
1996–2011	.	.	3.99 (±0.04, 1157)

[1] Pooling nests from all years.

Table 7. Annual means (± SE, n) of reproductive parameters of Canada Geese nesting at the primary study area on the Polemond River, along eastern Hudson Bay in northern Quebec, 1997–2003.

Parameter	1997	1998	1999	2000	2001	2002	2003	Years Pooled
Clutch size (CS)	4.98 (±0.09, 113)	5.29 (±0.10, 102)	4.65 (±0.07, 162)	4.05 (±0.11, 111)	4.49 (±0.07, 322)	3.63 (±0.12, 73)	4.52 (±0.06, 248)	4.54 (±0.03, 1131)
Clutch size at hatch (CSH)	4.47 (±0.08, 227)	4.72 (±0.07, 301)	3.75 (±0.08, 253)	3.45 (±0.12, 87)	4.30 (±0.05, 534)	3.03 (±0.08, 177)	3.93 (±0.06, 498)	4.08 (±0.03, 2077)
Goslings leaving nest (GLN)	4.16 (±0.09, 231)	4.26 (±0.07, 298)	3.45 (±0.08, 248)	2.98 (±0.12, 84)	3.77 (±0.05, 532)	2.71 (±0.08, 174)	3.51 (±0.06, 501)	3.66 (±0.03, 2068)
Mayfield nesting success (%)	81.9 (±0.1, 35) [76.6-87.6][1]	89.4 (±0.1, 27) [85.6-93.3]	61.3 (±0.1, 124) [56.2-67.0]	20.4 (±0.3, 239) [16.6-25.1]	81.7 (±0.1, 92) [78.3-85.2]	50.8 (±0.2, 105) [44.5-57.9]	77.6 (±0.1, 102) [73.8-81.6]	67.3 (±0.04, 724) [65.4-69.4]
Successful nests (%) (Apparent nesting success)	82.5 (±2.2, 292)	86.8 (±1.8, 348)	64.3 (±2.3, 423)	23.0 (±2.1, 383)	84.2 (±1.4, 639)	55.1 (±2.8, 325)	75.7 (±1.7, 675)	69.1 (±0.8, 3085)
Abandoned nests (%)	0.7 (±0.5, 292)	0.3 (±0.3, 348)	0.7 (±0.4, 423)	3.4 (±0.9, 383)	0.3 (±0.2, 639)	1.8 (±0.7, 325)	1.3 (±0.4, 675)	1.2 (±0.2, 3085)
Destroyed nests (%)	15.4 (±2.1, 292)	9.8 (±1.6, 348)	34.5 (±2.3, 423)	73.4 (±2.3, 383)	15.5 (±1.4, 639)	43.1 (±2.7, 325)	23.0 (±1.6, 675)	29.2 (±0.8, 3085)
Other/unknown (%)	1.4 (±0.7, 292)	3.2 (±0.9, 348)	0.5 (±0.3, 423)	0.3 (±0.3, 383)	0.0 (±0.0, 639)	0.0 (±0.0, 325)	0.0 (±0.0, 675)	0.6 (±0.1, 3085)

[1] 95% Confidence Interval.

Pooling years (1996–2005), among the three zones there was a significant difference in clutch size (F=58.49, df=2, P<0.001). Post-hoc tests (Tukey's studentized test) showed that mean clutch size was significantly larger at the primary study area (4.54 eggs) than at the Hudson Bay secondary sites (4.09) and Ungava Bay sites (4.03) (Table 6). Annual mean clutch size of Hudson Bay sites were significantly different from that for Ungava Bay sites in 1998, 2001, and 2002. Long-term average for clutch size of the individual secondary sites ranged from 3.8 to 4.2 eggs at Hudson Bay (Appendix 18) and from 3.9 to 4.1 eggs at Ungava Bay (excluding sites surveyed <5 years, i.e., Cape Naujaat and False River) (Appendix 19).

For the primary study area (1997–2003) and secondary sites (1996–2005) along Hudson Bay and Ungava Bay, annual mean clutch size was positively correlated with annual mean temperature (4–24 May) (primary study area: r=0.77, P=0.04; Hudson Bay: r=0.90, P<0.01; Ungava Bay: r=0.77, P<0.01) and negatively correlated with clutch initiation date (primary study area: r=-0.83, P=0.02; Hudson Bay: r=-0.85, P<0.01; Ungava Bay: r=-0.90, P<0.01) (see Figures 7, 8, and 9). Including 2006–2011 for Ungava Bay sites the correlation of clutch size with temperature (r=0.85) and clutch initiation date (r=-0.88) were relatively unchanged.

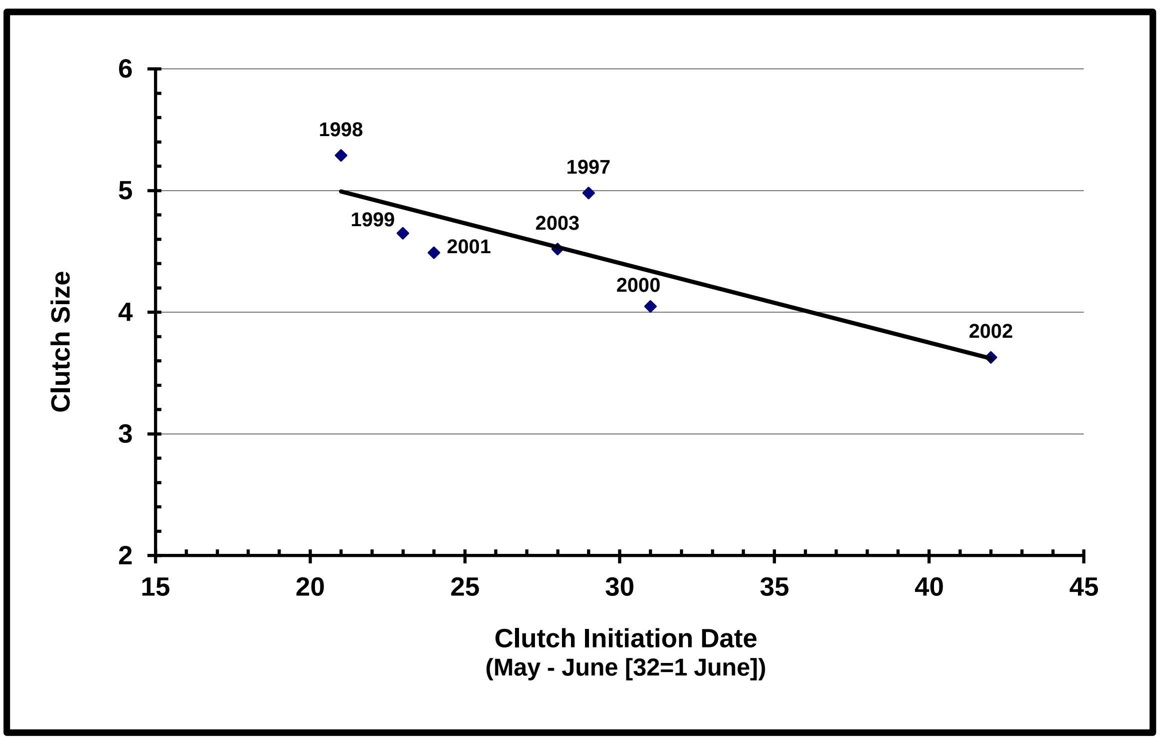

Figure 7. Regression of annual mean clutch size on clutch initiation date at the primary study area, 1997–2003.

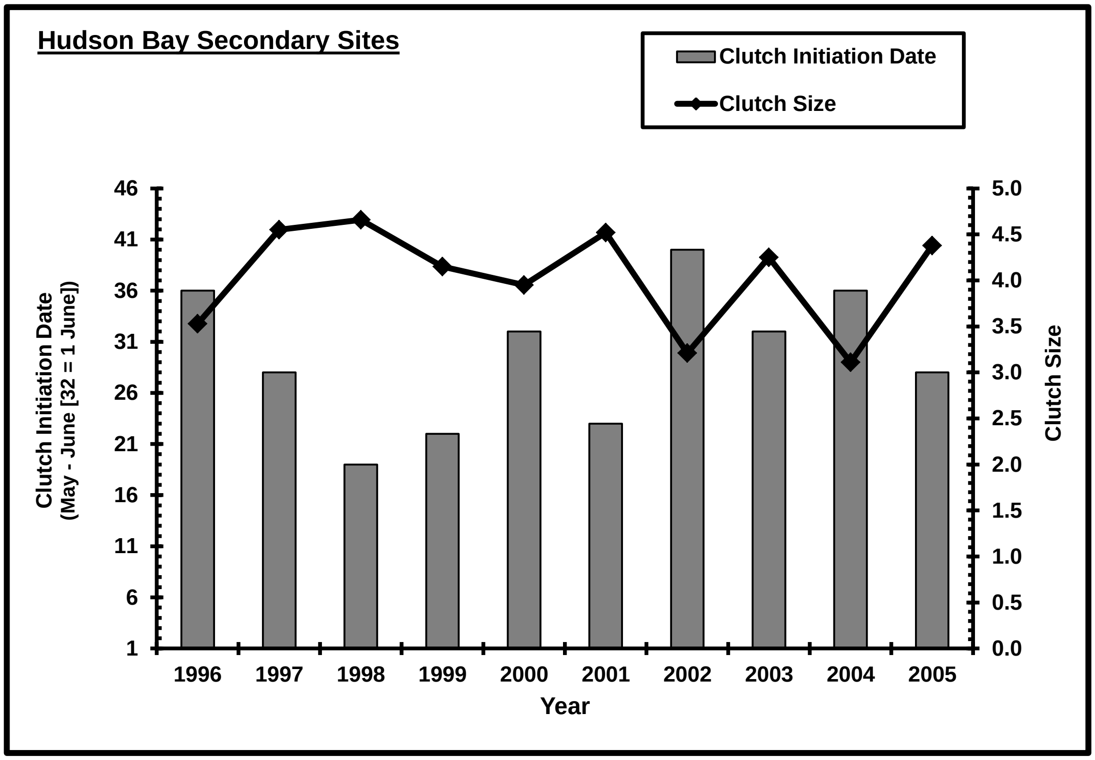

Figure 8. Atlantic Population Canada Goose annual mean clutch initiation date and clutch size for the Hudson Bay secondary sites, northern Quebec, 1996–2005.

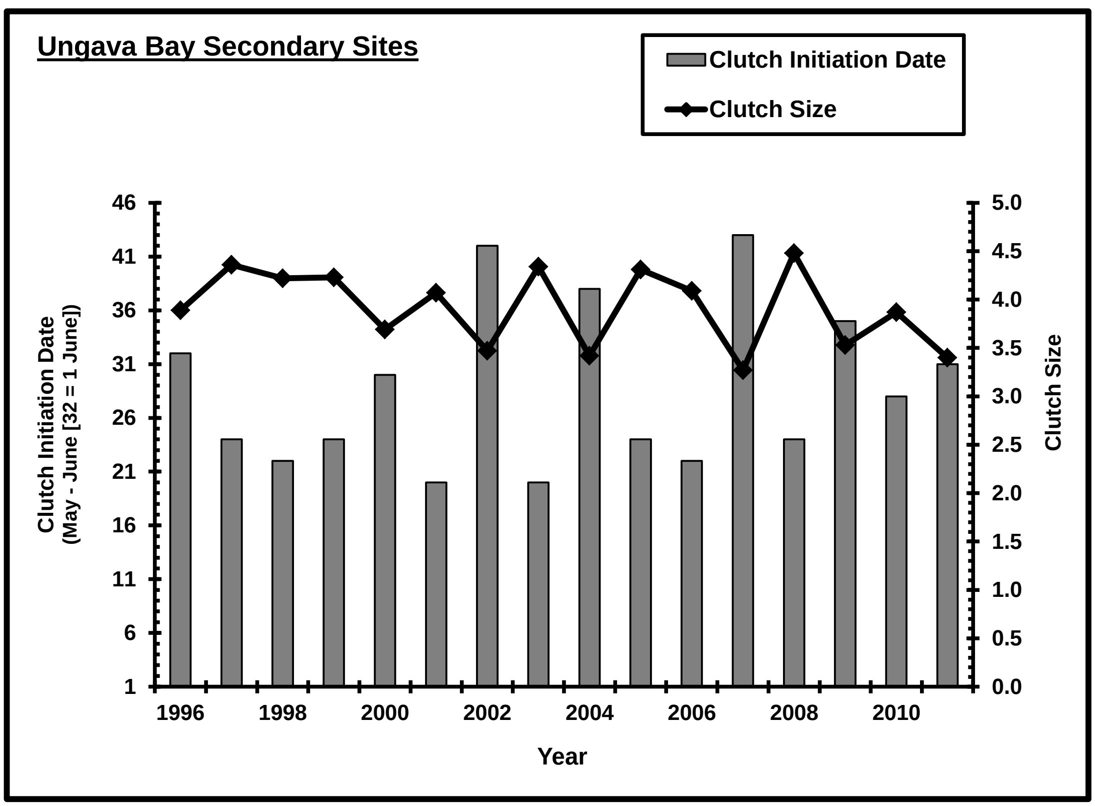

Figure 9. Atlantic Population Canada Goose annual mean clutch initiation date and clutch size for the Ungava Bay secondary sites, northern Quebec, 1996–2011.

Fate was determined for 99.9%, 99.5% and 95.5% of all nests found (1996–2005) on the primary study area and on the Hudson Bay and Ungava Bay secondary sites, respectively. For the primary study area, the overall mean (years pooled) Mayfield and apparent nesting success (i.e., the proportion of all nests initiated that hatched at least one gosling) was 67% and 69%, respectively (Table 7). The proportion of nests that were abandoned or destroyed ranged from <1% to 3% and from 10% to 73%, respectively (Table 7). The annual mean apparent nesting success was not significantly correlated with the annual mean temperature (4–24 May) ($r=0.62$, $P=0.13$) nor with annual mean clutch initiation date ($r=-0.50$, $P=0.25$).

Mean apparent nesting success (1996–2005) differed among years at the primary study area ($G=556.1$, $df=6$, $P<0.01$), the Hudson Bay secondary sites (pooled) ($G=100.7$, $df=9$, $P<0.01$) and the Ungava Bay secondary sites (pooled) ($G=149.2$, $df=9$, $P<0.01$). In each year of the study, nesting success was higher along Hudson Bay than at the Ungava Bay (Table 8), and the difference was significant ($P<0.05$; G-tests) in every year except 1997 ($P=0.07$). Along Hudson Bay, pooling years, the overall mean nesting success of individual secondary sites was similar, varying between 71% and 82% (Appendix 20). Along Ungava Bay, however, between 1996 and 2011 nesting success among the secondary sites varied by a considerable margin, between 11% and 66%; if sites that were surveyed in fewer than 5 years are excluded then this range is smaller, between 41% and 66% (Appendix 21).

For Hudson Bay and Ungava Bay, the percentage of nests abandoned never exceeded 4% in any one year, the exception being in 2000 at Ungava Bay when 24% (19 of 80 nests) were abandoned, likely due to a late-season snow fall in mid-June. For these two regions, the percentage of nests destroyed across years was 22.1% (386 of 1749) and 45.8% (487 of 1064), respectively.

Table 8. Mean annual apparent nesting success (%) (± SE, n) of Canada Geese on the primary study area and secondary study sites (all sites pooled) along Hudson Bay and Ungava Bay in northern Quebec, 1996–2011.

	Apparent Nesting Success (%)		
Year	Primary Study Area	Hudson Bay	Ungava Bay
1996	.	72.4 (±5.9, 58)	12.5 (±8.5, 16)
1997	82.5 (±2.2, 292)	78.0 (±3.7, 123)	60.7 (±9.4, 28)
1998	86.8 (±1.8, 348)	89.8 (±2.7, 127)	77.0 (±5.4, 61)
1999	64.3 (±2.3, 423)	77.7 (±3.7, 130)	60.2 (±4.6, 113)
2000	23.0 (±2.2, 383)	49.7 (±4.0, 159)	27.5 (±5.0, 80)
2001	84.2 (±1.4, 639)	85.5 (±2.3, 228)	49.7 (±3.7, 181)
2002	55.1 (±2.8, 325)	68.3 (±3.6, 167)	22.7 (±3.1, 185)
2003	75.7 (±1.7, 675)	75.1 (±2.6, 273)	63.6 (±3.2, 225)
2004	.	82.9 (±2.8, 187)	20.3 (±5.3, 59)
2005	.	83.8 (±2.1, 297)	56.9 (±4.6, 116)
2006	.	.	50.8 (±4.5, 126)
2007	.	.	31.3 (±5.8, 64)
2008	.	.	68.2 (±5.8, 66)
2009	.	.	46.8 (±6.4, 62)
2010	.	.	78.6 (±5.5, 56)
2011	.	.	48.0 (±10.2, 25)
Long-term average[1] 1997–2003	69.1 (±0.8, 3085)	74.9 (±1.2, 1207)	49.1 (±1.7, 873)
Long-term average[1] 1996–2005	.	77.2 (±1.0, 1749)	47.8 (±1.5, 1064)
Long-term average[1] 1996–2011	.	.	49.4 (±1.3, 1463)

[1] Pooling nests from all years.

Gosling survival and population productivity

Gosling survival (at approximately 5–6 weeks of age) at the primary study area was relatively stable among years, ranging between 57% and 63% in 5 of 7 years (Table 9). In the other 2 years it was much lower (42% and 48%). The year 2000, in addition to having the lowest gosling survival of any year, also had the lowest Mayfield nest success and the lowest mean number of goslings leaving the nest. The product of nest density and these three variables yields the number of goslings per km^2, or productivity index (PI). The PI ranged from a low of only 3.0 goslings/km^2 in 2000 to a high of 32.0 in 2003 (Table 9).

Table 9. Gosling survival and productivity index of Canada Geese nesting at the primary study area on the Polemond River, along Hudson Bay in northern Quebec, 1997–2003.

Parameter	1997	1998	1999	2000	2001	2002	2003
Broods marked[1]	211	278	237	75	472	166	455
Broods recaptured[2]	89	124	93	10	159	45	142
% Broods recaptured	42.2	44.6	39.2	13.3	33.7	27.1	31.2
Goslings marked	842	1166	804	225	1799	465	1558
Goslings recaptured	215	295	210	16	284	81	277
% Gosling survival[3]	58.9	57.1	63.4	41.7	47.5	58.4	57.0
	(±3.2)	(±2.5)	(±2.9)	(±8.6)	(±2.1)	(±4.3)	(±2.4)
Nest density (nests/km^2)	8.9	10.6	12.9	11.7	19.5	9.9	20.6
Nest success (Mayfield)	0.819	0.894	0.613	0.204	0.817	0.508	0.776
Goslings leaving the nest (GLN)	4.16	4.26	3.45	2.98	3.77	2.71	3.51
Gosling survival (GSURV)	0.589	0.571	0.634	0.417	0.475	0.584	0.570
Productivity index[4] (goslings/km^2)	17.9	23.1	17.3	3.0[5]	28.5	8.0	32.0

[1] One or more goslings in the brood was marked with a tag.
[2] One or more marked goslings was recaptured at banding.
[3] Mean of (*number of goslings recaptured* / *number of goslings marked*) for each brood, with ±SE in parentheses; sample size (n) is the number of marked broods.
[4] Calculated as the product of nest density, nest success (Mayfield), GLN, and GSURV.
[5] May be overestimated relative to other years: the *proportion* of marked broods recaptured at banding was much lower than average suggesting that the rate of total brood loss may have been high.

Over the larger geographical area encompassing the secondary study sites, another index of productivity is the ratio of immatures (i.e., goslings) to adults (I:A) captured in banding drives, when goslings are 4–6 weeks old. Over the course of this study (1996–2011), the observed I:A ratio ranged from 1.05 (in 2000) to 1.95 (in 2008) (Appendix 7).

Gosling growth

At approximately 6 weeks of age (i.e., age ranging between 39 days and 45 days), web-tagged goslings captured during the annual banding drives on the primary study area (years pooled, 1997–2003) had a mean head length of 96.5 mm (± 3.6 [SD], n=809), mean culmen length of 40.3 mm (± 2.9, n=809), mean tarsus (bone) length of 81.7 mm (± 3.9, n=809), mean tarsus (total) length of 97.2 mm (± 4.6, n=589), mean 9th primary length of 106.5 mm (± 22.7, n=808), and a mean mass of 1964 g (± 261, n=809) (see Appendix 22) (Note: goslings whose age >30 days and head length <80 mm were considered outliers and therefore excluded from all analyses). Regression of these morphological measurements on age are presented in Appendix 23. This compares with the measurements of captive-fed goslings in 2003 at age 41 days: mean head length of 103.2 mm, mean culmen length of 44.3 mm, and a mean mass of 2760.2 g (see Appendix 24 for all measurements by age). Regression of these morphological measurements on age are presented in Appendix 25.

Brood surveys and movements

From 1996 to 2001, the annual helicopter brood surveys in the Hudson Bay lowlands were conducted between 23 July and 4 August (Table 10). Brood density varied from a low of 0.30 brood/km^2 in 2000 to a high of 1.39 in 2001, while brood size ranged from 2.96 goslings/brood in 1999 to 3.81 in 1998 (Table 10). These two variables were weakly positively correlated (r=0.79, P=0.06). There was a correlation between brood density and clutch initiation date (negative; r=-0.90, P=0.02) and clutch size (positive; r=0.79, P=0.06) for the Hudson Bay secondary nesting sites (pooled). Mean brood size from the brood survey was weakly positively correlated with both clutch size (r=0.78, P=0.07) and nesting success (r=0.75, P=0.09) for these secondary sites.

Table 10. Atlantic Population Canada Goose brood-related results from surveys and banding program in Hudson Bay lowlands in northern Quebec, 1996–2013.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Mean hatching date[1]	4 July	27 June	19 June	21 June	1 July	22 June	8 July	1 July	4 July	27 June
Primary study area (Polemond River)										
Brood observation dates	.	11 - 21 July	1 - 27 July	24 June - 23 July	11 - 29 July	22 June - 30 July	6 July - 13 August	25 June - 9 August	.	.
Mean brood size (± SD, n broods)	.	3.91 (± 1.65, 198)	3.92 (± 1.71, 416)	3.39 (± 1.44, 193)	3.07 (± 1.86, 14)	4.19 (± 1.70, 161)	2.71 (± 1.27, 224)	3.33 (± 1.43, 679)	.	.
Helicopter brood survey[2]										
Survey Dates	23 - 24 July	24 - 26 July	25 - 28 July	25 - 29 July	1 - 4 August	27 - 31 July	.	.	.	.
Brood density (n/km^2) (± SE, n transects)	0.30 (± 0.05, 10)	0.63 (± 0.12, 10)	1.37 (± 0.27, 8)	0.82 (± 0.13, 10)	0.20 (± 0.07, 10)	1.39 (± 0.18, 10)	.	.	.	.
Mean brood size (± SD, n broods)	3.18 (± 0.97, 115)	3.47 (± 1.17, 137)	3.81 (± 1.42, 132)	2.96 (± 1.46, 102)	3.00 (± 1.41, 14)	3.68 (± 1.77, 134)	.	.	.	.
Fixed-wing June breeding pair survey[2]										
Breeding pair density (n/km^2) (± SE, n transects)	0.59 (± 0.09, 9)	0.81 (± 0.17, 9)	0.48 (± 0.09, 9)	0.88 (± 0.18, 9)	0.70 (± 0.11, 9)	2.20 (± 0.34, 6)	.	.	.	.
Brood : breeding pair ratio[3]	0.51	0.78	2.85	0.93	0.29	0.63	.	.	.	.
Helicopter banding program[4]	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Banding-observation dates	.	28 July - 9 August	29 July - 8 August	30 July - 9 August	5-15 August	1-11 August	7-18 August	2-11 August	6-15 August	1-11 August
Mean brood size (± SD, n broods)	.	3.14 (± 1.30, 44)	3.62 (± 1.41, 74)	3.45 (± 1.28, 100)	3.03 (± 1.08, 60)	3.38 (± 1.39, 34)	3.17 (± 1.50, 178)	3.27 (± 1.10, 78)	2.93 (± 1.26, 43)	3.28 (± 1.23, 215)
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**Average (1997–2013)**	
Banding-observation dates	31 July - 13 August	6-14 August	2-9 August	5-13 August	6-14 August	5-18 August	4-14 August	3-12 August		
Mean brood size (± SD, n broods)	3.10 (± 1.31, 196)	2.54 (± 1.10, 156)	3.17 (± 1.34, 167)	2.58 (± 1.22, 65)	2.66 (± 1.12, 82)	2.57 (± 0.86, 30)	2.86 (± 0.66, 14)	2.49 (± 1.08, 86)	3.05 (± 1.29, 1622)	

[1] Hudson Bay secondary sites.
[2] Adapted from Hughes 2001 and Hughes 2002 (data for selected transects originally provided by W.F. Harvey, J. Rodrigue, and A. Bourget).
[3] Ratio of the brood density(helicopter brood survey) and breeding pair density.
[4] Adapted from Cotter 2014.

The annual mean size of broods observed on the primary study area, 1997–2003, ranged from 2.7 to 4.2 goslings (Table 10). Pooling years, the mean size of broods declined over the summer periods: 3.58 goslings at 0 weeks old (i.e., hatch to 7 days old), 3.54 goslings at 2 weeks, 3.44 goslings at 4 weeks, and 3.00 goslings at 6 weeks. The mean annual brood size was positively correlated with mean annual clutch size (CS) ($r=0.79$, $P=0.03$), mean annual number of goslings leaving the nest (GLN) ($r=0.90$, $P<0.01$), and mean brood size from helicopter brood survey (1997–2001: $r=0.90$, $P=0.04$), and negatively correlated with mean annual clutch initiation date ($r=-0.77$, $P=0.04$).

The mean size of broods observed from the helicopter during flights to locate brood flocks for banding was weakly positively correlated with annual mean clutch size of Hudson Bay secondary sites (1997–2005: $r=0.67$, $P=0.046$) but was not correlated with either mean brood size from the aerial brood survey (1997–2001: $r=0.49$, $P=0.41$) or mean brood size from the primary study area (1997–2003: $r=0.52$, $P=0.24$) (Table 10). Although there was not a significant correlation, the annual mean size of broods observed during the banding flights did track the annual mean brood size from the helicopter brood survey (Figure 10).

The distance moved by goslings web-tagged at hatch on the primary study area on the Polemond River to the time they were captured at 4–6 weeks of age during banding drives varied from as little as 56 m to as high as 61 km, with an overall average across years of 7237 m (Table 11; Figure 11). The overall median distance, across years, was 4.0 km, with annual medians varying between 1.4 km and 7.3 km. For 1999–2003, 90% of all movements each year were less than 18 to 24 km.

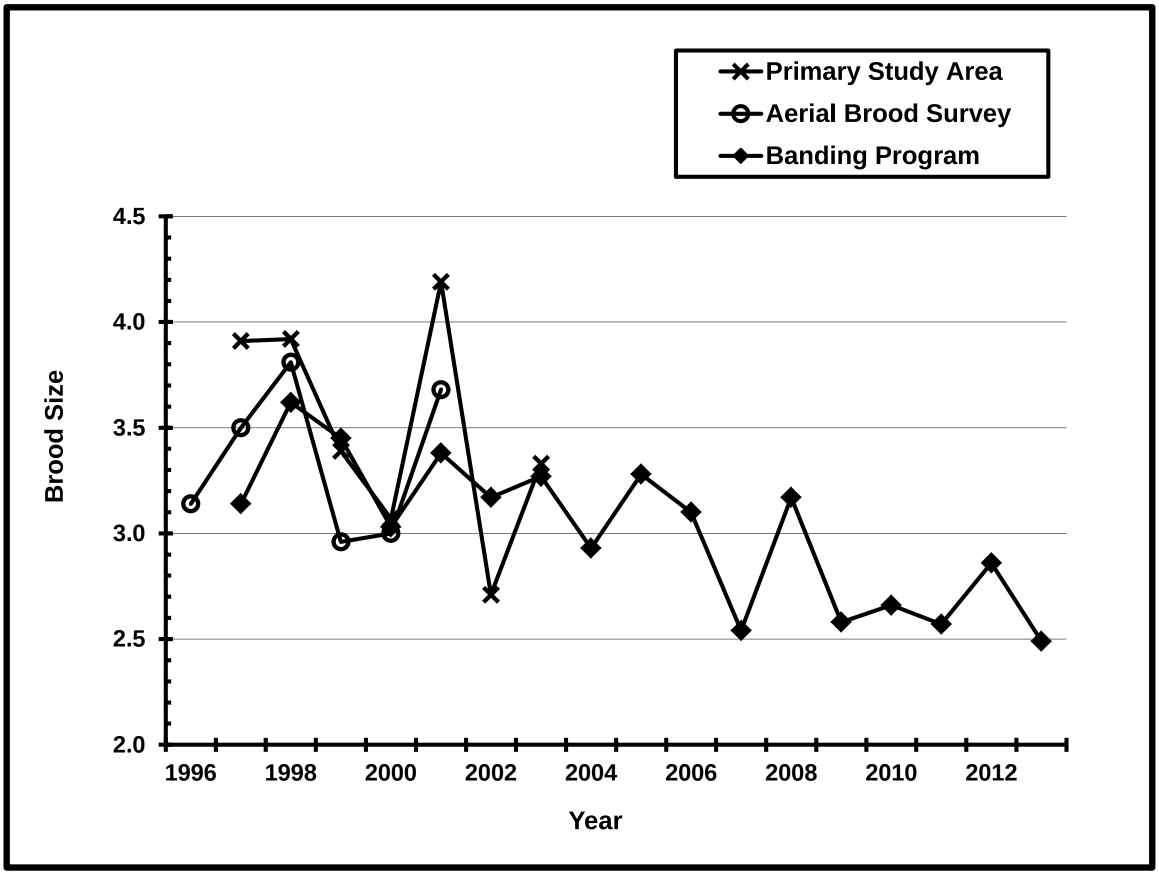

Figure 10. Mean size of Atlantic Population Canada Goose broods observed during ground brood surveys on the primary study area, aerial brood surveys, and helicopter flights over Hudson Bay coastal lowlands searching for moulting family groups to capture and band, 1996–2013.

Table 11. Distances (m) travelled by Atlantic Population Canada Goose goslings web-tagged on the primary study area between nests and banding locations, 1997–2003.

Year	N	Median	Mean	SE	Minimum	Maximum	90% quantile
1997	215	1417	1554	69	98	5301	2823
1998	297	3610	4667	241	56	19,131	8580
1999	209	4057	7809	546	1008	47,290	20,627
2000	16	5093	6384	1684	1284	19,784	19,606
2001	282	5671	9359	537	242	58,273	18,192
2002	80	3275	7756	1034	198	55,658	22,058
2003	265	7309	11,914	772	1040	60,878	23,573
Years Pooled	1364	3977	7237	239	56	60,878	18,800

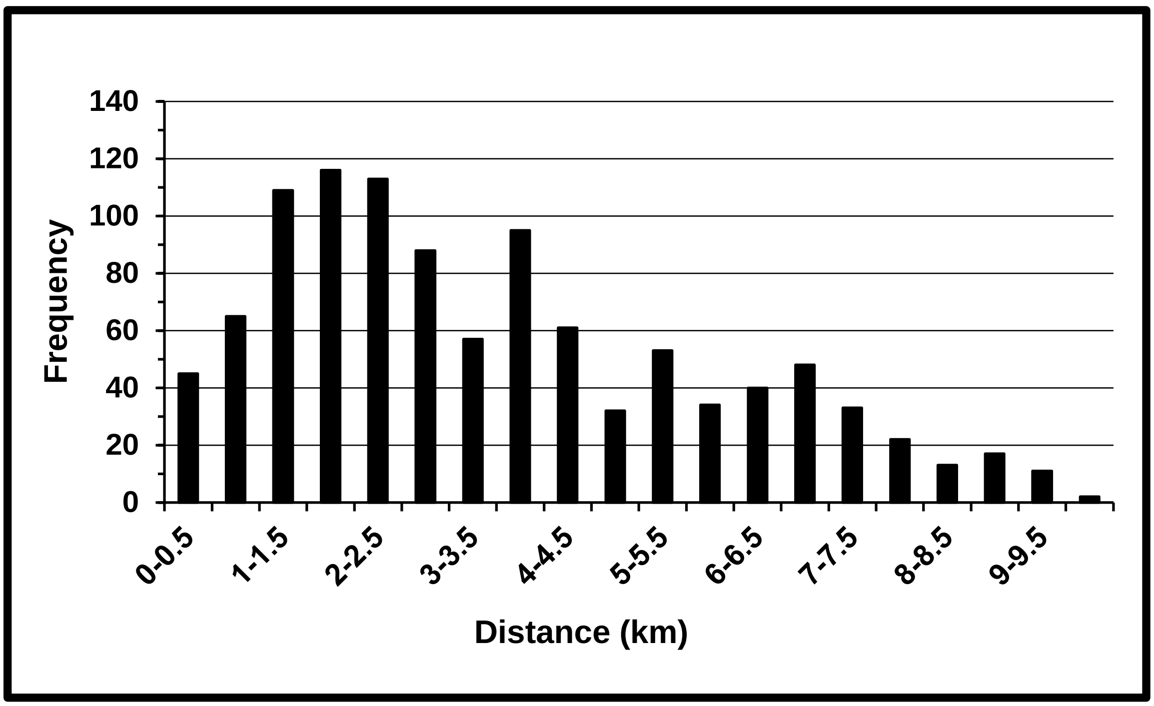

Figure 11. Frequency of distances travelled by Atlantic Population Canada Goose goslings web-tagged on the primary study area to banding locations (number of goslings per 0.5 km classes; years pooled), 1997–2003.

Diet during brood-rearing (from Cadieux et al. 2005)

For her Master's thesis, Marie-Christine Cadieux studied the diet of adult Canada Geese and their goslings on the primary study area during the brood-rearing season in 2001, using esophageal contents from 25 adult females, 27 adult males, and 59 goslings (Cadieux 2002). The following is a brief summary of results she published in a scientific article in 2005 (Cadieux et al. 2005). During the first four weeks of brood-rearing, the diet of adult Canada Geese was primarily graminoids (>65%), especially the leaves of the short form of *Carex aquatilis* and *Eriophorum* spp., which has the highest nitrogen concentration (2.5–3.5%). Graminoids were also important for goslings, however, they consumed a greater variety of other plant species (68%) than adults, especially in the first two weeks. Later in the brood-rearing period, adults shifted to a diet composed mainly of berries (>40%, mostly *Empetrum nigrum*) whereas goslings consumed fewer berries (24%) and maintained a higher proportion of nitrogen-rich plants in their diet (53% leaves, mostly graminoids) than adults, presumably to complete their growth. Plant species consumed by geese over the summer indicated a preference for high quality plants (i.e., those with a high nitrogen concentration).

Nest predation and small mammal abundance

The percentage of nests destroyed annually by predators ranged between 10% and 73% at the primary study area (Table 7), between 10% and 48% at the Hudson Bay secondary sites, and between 16% and 88% at the Ungava Bay secondary sites (Figure 12). Across years, the type of predator (or species) was identified for 92% of all predator-destroyed nests at the primary study area, for 51% of nests at Hudson Bay and for 47% at Ungava Bay. At the primary study area, over the 7-year period of the study (1997-2003), the percent of depredated nests did not correlate with mean clutch initiation date ($r=0.51$, $P=0.24$) nor with the density of nests ($r=-0.22$, $P=0.63$). At all three zones, the two dominant predator types were foxes (primarily Arctic Fox but also Red Fox) and avian (Table 12). The number of Arctic Foxes observed by the crew on the study area each field season were as follows: 1997, n=16; 1998, n=16; 1999, n=54; 2000, n=48; 2001, n=27; 2002, n=54; 2003, n=48.

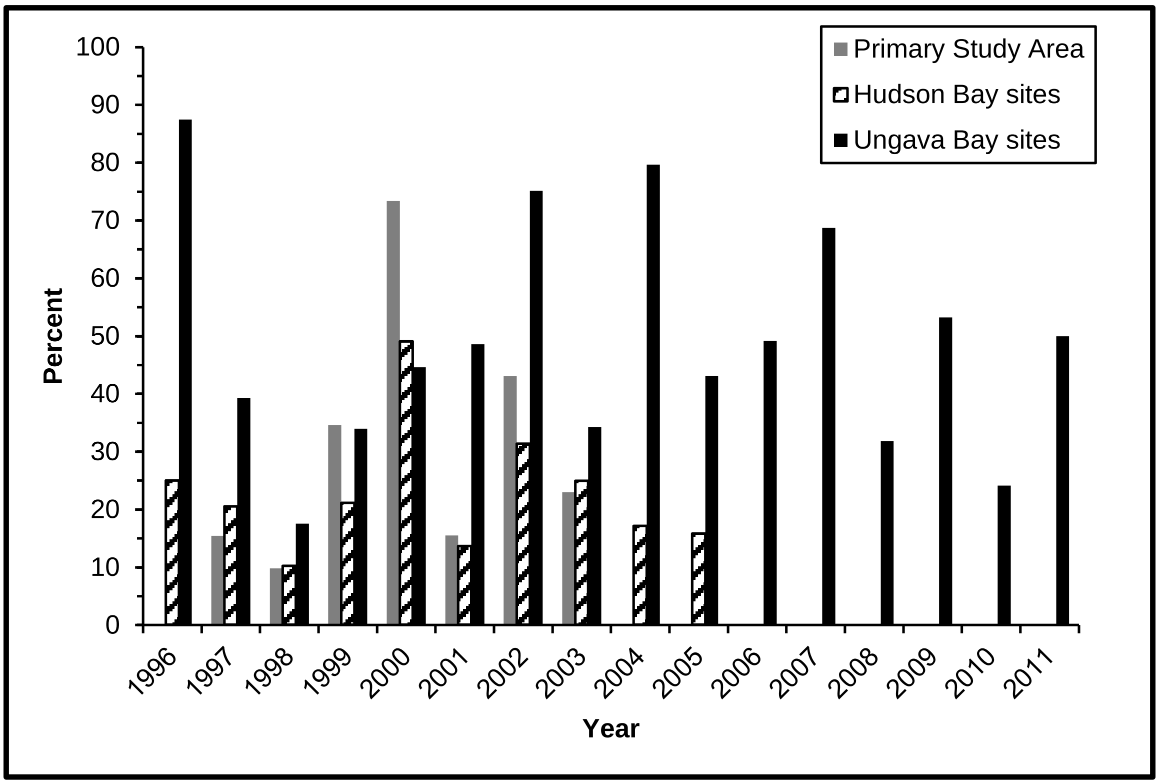

Figure 12. Percentage of Canada Goose nests destroyed by predators at the primary study area and at the Hudson Bay and Ungava Bay secondary sites, 1996–2011.

Table 12. Percentage of destroyed Canada Goose nests by predator species or type, at the primary study area, Hudson Bay secondary sites, and Ungava Bay secondary sites in northern Quebec, 1996–2005.

Predator	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Primary study area										
Avian	.	7	6	3	7	4	16	15	.	.
Bear	.	0	0	0	0	0	0	0	.	.
Caribou	.	2	0	0	0	0	0	0	.	.
Fox	.	69	88	80	77	81	76	75	.	.
Gull	.	0	6	2	2	7	5	8	.	.
Jaeger	.	0	0	0	2	0	2	0	.	.
Unknown	.	22	0	15	11	8	1	1	.	.
Total (%)	.	100	100	100	100	100	100	100	.	.
Hudson Bay secondary sites										
Avian	0	0	0	0	3	0	27	31	0	0
Bear	0	0	0	0	0	0	0	0	0	0
Caribou	0	0	0	0	0	0	0	0	0	0
Fox	0	0	0	59	61	13	63	68	0	0
Gull	0	0	0	0	3	10	4	1	3	0
Jaeger	0	0	0	0	0	0	6	0	0	0
Unknown	100	100	100	41	34	77	0	0	97	100
Total (%)	100	100	100	100	100	100	100	100	100	100
Ungava Bay secondary sites										
Avian	0	0	0	9	0	2	33	37	2	0
Bear	0	0	0	0	0	0	26	17	2	0
Caribou	0	0	0	0	0	0	0	0	0	0
Fox	0	0	0	31	64	27	34	29	0	2
Gull	0	0	0	0	0	7	2	5	0	0
Jaeger	0	0	0	0	0	0	3	0	0	0
Unknown	100	100	100	60	36	64	2	11	96	98
Total (%)	100	100	100	100	100	100	100	100	100	100

The number of small mammals captured, per 100 trap-nights, on the primary study area varied between 0.48 and 0.85 in the low years of 1998 through to 2001 and then increased three-fold to 3.16 in 2002 and 2.91 in 2003 (Table 13). With the exception of 2001, 80% or more of the small mammals captured were Ungava Lemmings, with the remainder being either Gapper's Red-backed Voles (*Clethrionomys gapperi*) or Meadow Voles (*Microtus pennsylvanicus*). On the study area (1998–2003), small mammal abundance did not correlate with the percent of nests destroyed by predators (r=-0.05, P=0.93), Mayfield nesting success (r=0.06, P=0.91) nor clutch size (r=-0.46, P=0.36).

Table 13. Number of Ungava Lemmings and voles caught and total number of small mammals captured per 100 trap-nights on the Canada Goose primary study area in northern Quebec, 1998–2003.

	1998	1999	2000	2001	2002	2003
Ungava Lemming	7	4	5	3	31	28
Vole	1	1	0	2	1	2
Total	8	5	5	5	32	30
Trap-nights (T-N)	938	951	1043	1046	1013	1030
Total caught/100 T-N	0.85	0.53	0.48	0.48	3.16	2.91

DISCUSSION

The size of the Atlantic Population (AP) of Canada Geese declined sharply in the late 1980s and early 1990s, from an estimated 118,000 breeding pairs in 1988 (Malecki and Trost 1990) to approximately 34,000 pairs in 1995 (Harvey and Rodrigue 2012). The primary factors responsible for this decline were high harvest pressure and below average gosling production (Hindman et al. 1996). By 2001 the population had mostly recovered, with an estimated 135,000 pairs; since 2002 the population has remained relatively stable with annual estimates ranging between 165,000 and 216,000 pairs (Harvey and Rodrigue 2012). The recovery can be attributed to two main factors: first, the measures implemented by the Atlantic Flyway Council in 1995, notably the closure of sport hunting seasons in most Atlantic Flyway states and provinces between 1995 and 1999—a preliminary analysis of Atlantic Population Canada Goose band recovery data by Boomer and Klimstra (2012) showed higher annual adult survival rates for 1997–1999 (range: 0.8668–0.9329) than for 2000–2008 (range: 0.7455–0.8644)—; and, second, 3 consecutive breeding seasons, 1997–1999, of good productivity that occurred while sport hunting seasons were closed. Productivity was particularly good in 1997 and 1998, as illustrated by results from our 7-year intensive breeding ecology study: these two years had the highest annual mean clutch size ($\geq$ 5 eggs), number of goslings leaving the nest (> 4), and Mayfield nesting success ($\geq$ 82%), as well as the lowest rate of destroyed nests ($\leq$ 15%). The recovery and increase in the size of the breeding population was matched by a strong increase in nest density, as demonstrated by an increase of 179% on the Hudson Bay secondary sites between 1996 and 2001. The increase in nest density and good nesting success and gosling survival in 4 of those 5 years resulted in a 59% increase in the number of goslings produced per km^2 over this 5-year period.

From the start of the annual breeding pair survey in 1993 to year 2000, the density of breeding pairs along Hudson Bay and Ungava Bay was similar (Harvey and Rodrigue 2005), but from 2001 to 2005 pair density doubled at Hudson Bay whereas at Ungava Bay it remained stable. Although we found no difference in clutch size between our secondary sites in the two areas, nesting success (years and sites pooled) was significantly higher at Hudson Bay sites than at Ungava Bay sites, 77% vs. 48%, which could have been a factor in the continued growth of the population along Hudson Bay. Habitat, population variables (such as predation), and climatic differences could also have played a role and need to be investigated further.

In most years, AP Canada Geese arrive on their breeding grounds in Nunavik, northern Quebec, during the first two weeks of May, a period when, as the snow melts, open ground appears and nest sites become available. In our study, we found that the mean temperature during this period, specifically 4–24 May, is an important factor influencing key breeding parameters. At the primary study area we found strong correlations between this temperature and clutch initiation date (negative) and clutch size (positive), and a weak positive correlation ($P=0.08$) with productivity index (number of goslings per km^2). In the three seasons of good productivity, 1997–1999 (see discussion above), the mean temperature for 4–24 May was above freezing (0 ºC) for both Hudson Bay and Ungava Bay (recorded at Puvirnituq and Kuujjuaq, respectively). Interestingly, between 1996 and 2011 there was only one other instance of consecutive years where this mean temperature was above freezing, and that was 2005 and 2006; in these two years both mean annual clutch size and nesting success were higher than their respective long-term averages. In their study of factors affecting clutch size in Canada Geese nesting on the western shore of Hudson Bay, MacInnes and Dunn (1988) determined that the interval between arrival and clutch initiation was an important factor, as the geese during that interval must use for maintenance some of their accumulated energy reserves that could have otherwise been used for egg production.

At all our study areas, nests were most commonly located on or near (≤ 10 m) the shore of a body of water and had dwarf birch as their primary plant cover. On the primary study area, the next most common nesting habitat was wet meadow, where 86% of all nests were situated on hummocks. On the main study area in 2001, Cadieux et al. (2005) found that from early June to early August Canada Goose use of pond margins in lichen-heath tundra was low while their use of wet sedge was much higher, particularly during hatching. Vegetation adjacent to a nest can be an important factor in its success as it can act as a barrier to predators and/or interact with defensive behaviour of nesting birds resulting in lower predation rates (see review by Miller et al. 2007). Dwarf birch is a common and widely distributed shrub in the lowlands along Hudson and Ungava bays (R.C. Cotter, pers. obs.), and on our primary study area Cadieux (2002:88) found this shrub represented, of the total percent cover (per habitat type), 15.3% in dry lichen-shrub habitat, 1.7% in riparian habitat, and 0.5% in wet sedge meadows. In dry habitat dwarf birch was over twice as common (% cover) as the next two most common vascular plants, crowberry (6.5%) and mountain cranberry (6.3%), while in wet sedge meadows two sedge species, *Carex aquatilis* (11.7%) and *C. rariflora* (7.1%), and cottongrass (8.9%) were the most common species (Cadieux 2002). After dwarf birch, crowberry and grasses were the next most important plants providing nest cover on Hudson Bay secondary sites, while along Ungava Bay willow and sedges were the next most common species providing cover.

As has been documented in other populations of arctic-nesting geese (Mickelson 1975; Leafloor et al. 2000; Lepage et al. 2000; Ely et al. 2008), in any given year AP Canada Geese were relatively synchronized in nest initiation, with 80% of clutches on the primary study area initiated during a 5- to 9-day period. In most years, the timing of nest initiation of these tundra-nesting AP geese is similar to taiga-nesting AP geese, for which Hughes et al. (2000) obtained annual means (1993–1996) that ranged from 18 to 25 May on their study area near the Laforge Reservoir (650 km southeast of our primary study area). AP Canada Geese nesting along Hudson Bay, i.e., on the main study area and on the secondary sites, laid similar sized clutches as AP geese nesting at Laforge (taiga): 4.5, 4.1, and 4.2 eggs, respectively (this study; Hughes et al. 2000). After an incubation period of 26 days, which is similar to the 25–28 days reported for other subspecies of Canada Goose (Mowbray et al. 2002), most AP geese nests hatched during the last 10 days of June. In the very late season of 2002, however, the mean hatching dates for the principal and the two secondary study areas were 8–11 July.

Whereas the number of breeding pairs began to stabilize after 2001, there was considerable variation in annual productivity; the productivity index on the primary study area was 28.5, 8.0 and 32.0 goslings/km^2 in 2001, 2002 and 2003, respectively. This was due to large annual changes in nest density, suggesting that once the population had recovered sufficiently, the main determinant of annual productivity was the propensity of breeding pairs to nest. The highest nest densities along Hudson Bay occurred the last year of the study (2003 in the primary study area, 2005 on secondary sites), so nesting habitat did not appear to be limited. Thus, propensity to nest may have been influenced more by the conditions of nesting habitats when the birds arrived on the breeding grounds than by the number of breeding pairs present.

In our study, 69.1% of nests initiated (2131of 3085 nests) at the primary study area were successful. This is very similar to the success rate of a sub-arctic population of *B. c. interior* breeding on Akimiski Island in James Bay—Gan (2012) reported a rate of 67.3% (2214 of 3292 nests) for the years 1997–2003 (adapted from Table 3.2) and 62.8% for 1993–2010. Our study found Arctic Foxes were responsible for approximately three-quarters of all nest depredation with the remainder primarily by avian predators, although in southern Ungava Bay Black Bears are also an important nest predator in some years. In most instances we were not able to identify the avian predator, but important arctic goose egg and nest predators, such as the Herring Gull, Glaucous Gull, Common Raven (*Corvus corax*), and jaegers (Mickelson 1975; Bruggink et al. 1994; Leafloor et al. 2000; Bêty et al. 2001; Wilson and Bromley 2001) were commonly observed in and around the study area (R.C. Cotter, unpublished data). Arctic Fox and Herring Gull are generalist predators (Pierotti and Good 1994; Angerbjörn et al. 1999; Bêty et al. 2001), that is, they have "several alternate prey species between which they may 'switch', depending on which prey species are currently most abundant" (Hanski et al. 1991). In northern Quebec, the main alternate prey of these two predators are small mammals, specifically lemmings and voles. Some studies of arctic-nesting geese have shown that nesting success and productivity are directly related to small mammal abundance, as predators—especially generalist predators such as Arctic Fox and Herring Gull (Pierotti and Good 1994; Angerbjörn et al. 1999; Bêty et al. 2001), both of which are common on the Ungava Peninsula—in years of low small mammal abundance will switch to goose eggs and nests (Bêty et al. 2001). Across the Canadian Arctic, small mammal populations fluctuate in a 3-4 year cycle (Krebs et al. 2002); this cycle was not observed on our primary study area along eastern Hudson Bay. For four consecutive years the population was very low and then it increased to a level > 3 times higher for each of the next two years. We did not observe any correlation between small mammal abundance and either nesting success or the productivity index.

In summary, for AP Canada Geese on the Ungava Peninsula, reproduction is good most years and the geese clearly have a very high reproductive potential. The most important factor affecting productivity is weather, specifically temperature and snow cover during the critical egg-laying and early incubation periods (late May–early June). These two variables have a direct effect on the timing of snowmelt and thus also affects the timing of nest-initiation and the propensity to nest. A late snowmelt delays the availability of suitable nesting habitat, which in turns delays the onset of nesting and even discourages many pairs from attempting to nest. Furthermore, those pairs that do nest lay smaller clutches and generally are less successful in having at least one gosling hatch.

The rapid recovery and current stability of the Atlantic Population of Canada Geese are the result of decisive actions taken by state, provincial, and federal wildlife agencies in the mid 1990s, coupled with the population's high productivity during the late 1990s and early 2000s. Of particular importance was the closure of sport hunting in Canada and the United States for a number of years in the mid and late 1990s, the development of an *Action Plan* in 1996 and the updated *Management Plan* in 2008 detailing objectives and strategies for the recovery/management of the population, and implementation (and funding) of three critically important annual breeding ground projects: a breeding pair survey, a nesting study, and a banding program. Those three projects shifted monitoring of the annual status of this population from the wintering grounds, where harvest and population estimates were confounded by the presence of other Canada Goose populations in the same areas, to the breeding grounds, where surveys, banding, and this nesting study have provided annual estimates of breeding population size, harvest rates, and survival rates as well as indices of productivity. That information enabled managers to reinstate the Atlantic Flyway's Canada Goose hunting seasons in a gradual manner that ensured continued growth of the population to its former numbers (Hindman et al. 2004).

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APPENDICES

Appendix 1. Coordinates of primary and secondary study sites of Atlantic Population Canada Geese in northern Quebec.

Study site	Latitude[1]	Longitude
Primary study area	59º 31.600'	77º 36.157'
Hudson Bay secondary sites		
Korak River	60º 45.912'	77º 32.383'
Sorehead River	60º 30.784'	77º 19.575'
Povungnituk Lake	60º 02.783'	77º 04.773'
Formel River	59º 58.701'	77º 10.435'
Kogaluk River	59º 34.361'	77º 20.048'
Polemond River	59º 27.889'	77º 22.315'
Mariet River	59º 09.645'	77º 48.378'
Ungava Bay secondary sites		
Tryon Plateau	59º 16.051'	69º 21.235'
Aupaluk	59º 15.541'	69º 19.270'
Qikirtajuaq Island	59º 07.003'	69º 11.907'
Cape Naujaat	58º 48.548'	66º 25.664'
Ragged Point	58º 48.079'	68º 28.611'
Kaslac-Basalte Lakes	58º 45.584'	68º 44.360'
False River	58º 32.346'	68º 00.305'
Dry Bay	58º 30.997'	68º 15.236'
Tasker Point	58º 25.587'	67º 44.579'
Big Island	58º 20.986'	67º 32.933'

[1] Coordinates are in datum NAD27 Canada

Appendix 2. Number, coordinates, and length of transects flown for annual aerial brood surveys and breeding pair surveys of Atlantic Population Canada Geese in northern Quebec.

Brood transect [1]	**Pair transect** [2]	**Latitude** [3]	**Longitude (west)**	**Longitude (east)**	**Length (km)**	**Longitude (east)-pair survey**	**Length (km)-pair survey**
1	–	60º 50'	77º 48'	76º 28'	75	.	.
2	8	60º 30'	77º 35'	76º 40'	50	76º 24'	65
3	7	60º 10'	77º 34'	76º 39'	50	76º 05'	80
4	6	59º 50'	77º 21'	76º 27'	50	76º 12'	65
5	5	59º 30'	77º 54'	76º 00'	110	75º 37'	130
6	4	59º 10'	78º 12'	76º 14'	110	76º 14'	110
7	3	59º 00'	78º 21'	76º 40'	95	76º 40'	95
8	2	58º 50'	78º 33'	76º 35'	115	76º 35'	115
9	22	58º 30'	77º 50'	77º 00'	50	77º 00'	50
10	1	58º 10'	77º 32'	76º 42'	50	76º 42'	50
11	–	60º 20'	77º 39'	76º 43'	50	.	.
12	–	60º 02'	77º 13'	76º 17'	50	.	.

[1] In 1996, brood transects 2–12 were surveyed; in 1997–2001, transects 1–10 were surveyed.
[2] "–" indicates that this brood transect did not correspond with a pair survey transect; pair survey data from W.F. Harvey, J. Rodrigue, and A. Bourget.
[3] Coordinates are in datum NAD27 Canada.

Appendix 3. Coordinates of the start of small mammal transects (trap lines) on the Canada Goose primary study area in northern Quebec, 1998–2003.

Transect[1]	Habitat	Latitude[2]	Longitude
1	lowland	59º 31.947'	77º 35.554'
2	lowland	59º 31.939'	77º 35.455'
3	upland	59º 31.651'	77º 35.038'
4	upland	59º 31.635'	77º 34.923'

[1] Start of transect, that is, location of trap #1; transect bearing = 190º.
[2] Coordinates are in datum NAD27 Canada.

Appendix 4. Weekly mean air temperature (part A) and total amount of precipitation (rain and snow) (part B) at the primary study area on the Polemond River, 1997–2003.

Week[1]	1997	1998	1999	2000	2001	2002	2003	Average 1997–2003
A) Temperature (ºC)								
1–7 May	-7.6	-1.3	2.4	-2.3	-1.5	-4.6	-5.1	-2.9
8–14 May	-1.4	3.2	-0.5	-3.6	-0.5	-6.9	-2.4	-1.7
15–21 May	3.5	4.4	-0.1	-0.7	5.3	-2.6	2.9	1.8
22–28 May	2.9	0.0	6.1	5.4	10.5	0.0	3.0	4.0
29 May–4 June	5.6	4.6	2.6	2.3	3.3	0.8	0.8	2.9
5–11 June	7.4	13.0	8.6	1.1	7.2	1.4	0.9	5.7
12–18 June	6.2	11.6	4.7	4.5	7.3	5.6	6.0	6.6
19–25 June	10.4	13.4	11.9	4.2	6.5	4.3	5.5	8.0
26 June–2 July	8.2	15.4	9.2	7.1	7.7	6.4	5.6	8.5
3–9 July	13.0	14.0	12.6	9.3	14.3	10.5	11.4	12.1
10–16 July	19.3	15.6	13.1	14.7	15.9	11.9	7.7	14.0
17–23 July	12.6	12.1	12.0	12.4	16.0	7.1	13.4	12.2
24–30 July	14.9	15.2	16.0	15.7	14.4	14.3	15.1	15.1
31 July–6 Aug	9.3	13.4	12.0	12.8	15.2	13.8	16.1	13.2
7–13 Aug	8.8	13.5	11.9	13.2	12.9	13.9	16.0	12.9
B) Precipitation (rain+snow) (mm)								
1–7 May	.	.	.	.	.	.	.	.
8–14 May	.	.	.	.	.	.	.	.
15–21 May	.	.	.	.	.	.	.	.
22–28 May	11.0	20.0	0.2	9.5	0.0	56.0	6.5	14.7
29 May–4 June	7.0	3.6	4.0	64.5	10.0	6.0	0.0	13.6
5–11 June	8.0	0.1	11.1	140.0	13.6	1.0	71.0	35.0
12–18 June	13.0	10.1	1.8	54.5	18.5	0.5	4.0	14.6
19–25 June	1.0	46.0	3.3	4.6	27.6	27.5	9.0	17.0
26 June–2 July	12.2	2.1	1.0	23.7	14.5	16.0	13.0	11.8
3–9 July	0.0	5.2	0.2	13.6	12.5	2.0	1.5	5.0
10–16 July	10.0	10.8	16.1	17.0	0.1	8.5	37.1	14.2
17–23 July	0.2	4.2	8.4	11.0	3.0	4.5	0.0	4.5
24–30 July	6.0	0.1	19.0	21.3	0.1	21.0	9.0	10.9
31 July–6 Aug	10.0	4.0	10.6	2.1	3.0	4.5	0.0	4.9
7–13 Aug	2.3	0.1	0.0	0.0	3.5	3.5	3.0	1.8

[1] For 1–21 May, the weekly mean temperatures are from the Puvirnituq Airport and the precipitation levels are not available.

Appendix 5. Mean annual clutch initiation date (± SE, n) of Canada Geese on the secondary study sites along Hudson Bay in northern Quebec, 1996–2005.

Site [1]	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Long-term average [2] 1996–2005
Korak River	.	28 May (±0.7, 16)	23 May (±0.8, 13)	29 May (±0.7, 17)	2 June (±0.2, 25)	23 May (±0.7, 36)	12 June (±1.0, 23)	31 May (±0.8, 40)	7 June (±0.8, 33)	31 May (±1.3, 66)	31 May (±0.5, 269)
Sorehead River	7 June (±1.2, 11)	29 May (±0.9, 20)	20 May (±1.1, 21)	26 May (±1.1, 25)	1 June (±0.4, 16)	24 May (±0.7, 32)	10 June (±1.5, 30)	28 May (±0.7, 49)	5 June (±1.4, 33)	31 May (±1.5, 46)	30 May (±0.5, 283)
Povungnituk Lake	6 June (±1.2, 10)	27 May (±1.2, 15)	19 May (±1.7, 10)	21 May (±1.6, 15)	2 June (±0.6, 20)	20 May (±0.9, 24)	7 June (±1.2, 17)	8 June (±1.9, 32)	3 June (±1.0, 31)	28 May (±1.0, 34)	30 May (±0.6, 208)
Formel River	7 June (±0.8, 13)	28 May (±0.7, 20)	20 May (±0.9, 25)	22 May (±1.7, 20)	4 June (±0.4, 19)	23 May (±0.8, 34)	9 June (±1.0, 22)	29 May (±0.9, 36)	6 June (±0.7, 25)	27 May (±1.0, 49)	29 May (±0.5, 263)
Kogaluk River	3 June (±0.8, 9)	29 May (±1.2, 15)	19 May (±0.7, 21)	20 May (±1.6, 14)	1 June (±0.6, 16)	23 May (±0.7, 23)	7 June (±0.9, 22)	6 June (±2.0, 30)	5 June (±0.9, 20)	26 May (±1.7, 32)	30 May (±0.7, 202)
Polemond River	3 June (±0.8, 12)	26 May (±0.9, 17)	18 May (±1.3, 17)	17 May (±1.0, 16)	30 May (±0.7, 21)	21 May (±0.7, 38)	9 June (±1.4, 23)	27 May (±0.6, 39)	5 June (±1.1, 16)	24 May (±1.0, 31)	27 May (±0.5, 230)
Mariet River	.	24 May (±1.2, 6)	16 May (±1.8, 7)	19 May (±1.6, 14)	31 May (±1.0, 8)	24 May (±1.3, 21)	9 June (±2.3, 16)	10 June (±3.1, 25)	5 June (±1.3, 18)	23 May (±1.1, 22)	30 May (±1.0, 137)

[1] Sites listed north to south.
[2] Pooling nests from all years.

Appendix 6-A. Mean annual clutch initiation date (± SE, n) of Canada Geese on the secondary study sites along Ungava Bay in northern Quebec, 1996–2005.

Site [1]	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Tryon Plateau	.	.	.	.	.	.	.	25 May (±2.4, 15)	.	.
Aupaluk	.	.	.	.	.	.	.	19 May (±1.0, 44)	.	24 May (±1.0, 40)
Qikirtajuaq Island	.	.	.	28 May (±0.8, 10)	30 May (±1.2, 10)	18 May (±0.7, 34)	11 June (±1.9, 17)	18 May (±3.7, 8)	7 June (±1.5, 12)	22 May (±1.1, 15)
Cape Naujaat	.	.	.	.	.	24 May (±0.0, 1)	19 June (±2.8, 3)	.	.	.
Ragged Point	.	.	.	.	.	22 May (±1.3, 37)	3 June (±3.0, 5)	20 May (±1.4, 23)	13 June (±1.5, 5)	28 May (±1.4, 4)
Kaslac/Basalte Lakes	.	25 May (±2.0, 8)	23 May (±1.7, 10)	28 May (±1.6, 10)	30 May (±0.8, 9)	19 May (±2.3, 3)	.	.	.	.
False River	.	.	.	.	.	.	7 June (±2.0, 12)	.	.	.
Dry Bay	.	.	.	.	.	.	5 June (±1.5, 29)	19 May (±3.0, 6)	.	26 May (±2.3, 9)
Tasker Point	1 June (±1.4, 12)	23 May (±1.1, 11)	22 May (±2.7, 9)	23 May (±2.7, 8)	31 May (±1.2, 5)	.	.	.	.	.
Big Island	.	.	22 May (±0.9, 36)	24 May (±0.8, 63)	30 May (±0.5, 48)	21 May (±0.7, 67)	14 June (±1.3, 71)	20 May (±1.7, 72)	4 June (±1.2, 10)	26 May (±2.2, 14)

[1] Sites listed north to south.

Appendix 6-B. Mean annual clutch initiation date (± SE, n) of Canada Geese on the secondary study sites along Ungava Bay in northern Quebec, 2006–2011.

Site[1]	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**Long-term average**[2] **1996–2011**
Tryon Plateau	22 May (±1.3, 12)	11 June (±1.2, 14)	.	6 June (±1.0, 14)	26 May (±0.9, 18)	.	31 May (±1.1, 73)
Aupaluk	21 May (±1.3, 17)	13 June (±1.7, 18)	24 May (±1.0, 38)	6 June (±0.9, 19)	29 May (±0.8, 34)	31 May (±0.9, 24)	27 May (±0.6, 234)
Qikirtajuaq Island	23 May (±1.8, 7)	12 June (±1.6, 12)	21 May (±1.1, 14)	31 May (±3.2, 9)	28 May (±2.9, 3)	.	28 May (±0.9, 151)
Cape Naujaat	.	.	.	.	.	.	13 June (±6.8, 4)
Ragged Point	15 May (±0.8, 2)	.	.	.	.	.	24 May (±1.1, 76)
Kaslac/Basalte Lakes	.	.	.	.	.	.	26 May (±0.9, 40)
False River	.	.	.	.	.	.	7 June (±2.0, 12)
Dry Bay	22 May (±1.6, 4)	13 June (±3.0, 3)	21 May (±2.4, 8)	31 May (±0.8, 3)	.	.	30 May (±1.3, 62)
Tasker Point	.	.	.	.	.	.	26 May (±1.0, 45)
Big Island	24 May (±3.2, 5)	9 June (±0.0, 1)	31 May (±3.8, 5)	5 June (±1.5, 10)	.[3]	.	28 May (±0.6, 402)

[1] Sites listed north to south.
[2] Pooling nests from all years.
[3] Search abandonded after finding only two depredated nests and because of the presence of Black Bears.

Appendix 7. Predicted (PRED-) and observed (OBS-) Atlantic Population Canada Goose clutch initiation date (CLINIT) and age ratio at banding (immature:adult, I:A) on the Ungava Peninsula, Quebec, 1996-2011. Predicted values based on models using average of daily mean temperatures (Cº) (TEMP) and total snowfall (cm).

	Hudson Bay			**Ungava Bay**			**Ungava Peninsula**			
	TEMP	**Clutch Initiation[1]**		**TEMP**	**Clutch Initiation[1]**		**TEMP**	**Snowfall**	**Immature:Adult[4]**	
Year	**4–24 May**	**PRED-CLINIT[2]**	**OBS-CLINIT**	**4–24 May**	**PRED-CLINIT[3]**	**OBS-CLINIT**	**1–31 May**	**1–30 June**	**PRED-I:A[5]**	**OBS-I:A**
1996	-5.4	8 June	5 June	-3.2	7 June	1 June	-1.4	2.2	1.28	.[6]
1997	0.2	28 May	28 May	2.0	27 May	24 May	1.5	0.6	1.55	1.53
1998	2.4	23 May	19 May	4.3	22 May	22 May	2.9	0.0	1.69	1.71
1999	0.9	26 May	22 May	2.7	26 May	24 May	2.8	11.0	1.50	1.40
2000	-1.4	31 May	1 June	-0.1	31 May	30 May	0.8	31.2	0.99	1.05
2001	3.5	21 May	23 May	5.6	19 May	20 May	4.8	0.4	1.84	1.89
2002	-4.6	7 June	9 June	-2.4	5 June	11 June	-1.1	4.4	1.27	1.26
2003	0.0	28 May	1 June	5.5	20 May	20 May	4.7	5.4	1.75	1.73
2004	-3.7	5 June	5 June	-1.1	3 June	7 June	-0.6	8.0	1.25	1.19
2005	0.2	28 May	28 May	3.9	23 May	24 May	4.7	1.0	1.83	1.58
2006	0.5	27 May	.	5.5	20 May	22 May	5.3	0.8	1.88	1.58
2007	-5.2	8 June	.	-3.0	7 June	12 June	-1.7	1.2	1.27	1.21
2008	2.6	22 May	.	6.2	18 May	24 May	5.54	0.0	1.91	1.95
2009	-5.9	9 June	.	-2.3	5 June	4 June	-1.9	3.6	1.21	1.09
2010	-1.7	1 June	.	0.3	31 May	28 May	1.18	0.4	1.53	1.42
2011	-4.1	6 June	.	-1.8	4 June	31 May	-1.0	1.2	1.35	1.07

[1] Clutch initiation date for secondary study sites; observed=OBS-CLINIT (from Table 2).
[2] Predicted clutch initiation date (PRED-CLINIT) for: Hudson Bay = -2.1043 × TEMP(4–24 May) + 27.9376.
[3] Predicted clutch initiation date (PRED-CLINIT) for: Ungava Bay = -2.1194 × TEMP(4–24 May) + 31.2453.
[4] Gosling to adult ratio in banding catches; observed=OBS-I:A (Cotter 2014).
[5] Predicted gosling to adult ratio (PRED-I:A) for:
Ungava Peninsula = 0.0869 × TEMP(1–31 May) + June snowfall × -0.0163 + 1.4334
(Dr. Eric Reed, CWS, unpublished).
[6] A "." indicates data not available (i.e., the banding program commenced only in 1997).

Appendix 8. Mean annual hatching date (± SE, n) of Canada Geese on the secondary study sites along Hudson Bay in northern Quebec, 1996–2005.

Site [1]	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**Long-term average** [2] **1996–2005**
Korak River	.	27 June (±0.7, 16)	22 June (±0.7, 13)	28 June (±0.7, 17)	2 July (±0.2, 25)	22 June (±0.6, 36)	10 July (±1.1, 23)	29 June (±0.8, 40)	6 July (±0.8, 33)	30 June (±1.3, 66)	30 June (±0.5, 269)
Sorehead River	7 July (±1.2, 11)	28 June (±0.8, 20)	19 June (±0.9, 21)	24 June (±1.0, 25)	2 July (±0.4, 16)	23 June (±0.7, 32)	8 July (±1.5, 30)	27 June (±0.7, 49)	4 July (±1.5, 33)	30 June (±1.4, 46)	29 June (±0.5, 283)
Povungnituk Lake	5 July (±1.1, 10)	27 June (±1.2, 15)	19 June (±1.7, 10)	20 June (±1.4, 15)	1 July (±0.4, 20)	20 June (±1.0, 24)	5 July (±1.1, 17)	8 July (±1.8, 32)	2 July (±1.0, 31)	27 June (±1.1, 34)	29 June (±0.6, 208)
Formel River	5 July (±0.9, 13)	27 June (±0.7, 20)	19 June (±0.8, 25)	20 June (±1.7, 20)	3 July (±0.1, 19)	22 June (±0.7, 34)	8 July (±1.1, 22)	28 June (±0.9, 36)	5 July (±0.7, 25)	26 June (±1.0, 49)	27 June (±0.5, 263)
Kogaluk River	2 July (±1.0, 9)	28 June (±1.1, 15)	19 June (±0.7, 21)	20 June (±1.6, 14)	30 June (±0.5, 16)	22 June (±0.8, 23)	7 July (±1.0, 22)	6 July (±2.0, 30)	4 July (±0.9, 20)	25 June (±1.7, 32)	28 June (±0.6, 202)
Polemond River	2 July (±0.9, 12)	26 June (±0.8, 17)	18 June (±1.3, 17)	17 June (±1.0, 16)	28 June (±0.5, 21)	21 June (±0.6, 38)	8 July (±1.3, 23)	26 June (±0.6, 39)	3 July (±1.0, 16)	24 June (±0.9, 31)	26 June (±0.5, 230)
Mariet River	.	24 June (±1.2, 6)	16 June (±1.5, 7)	18 June (±1.4, 14)	28 June (±0.5, 8)	23 June (±1.2, 21)	6 July (±2.4, 16)	10 July (±3.1, 25)	4 July (±1.3, 18)	23 June (±1.0, 22)	29 June (±1.0, 137)

[1] Sites listed north to south.
[2] Pooling nests from all years.

Appendix 9-A. Mean annual hatching date (± SE, n) of Canada Geese on the secondary study sites along Ungava Bay in northern Quebec, 1996–2005.

Site[1]	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Tryon Plateau	.	.	.	.	.	.	.	25 June (±2.4, 15)	.	.
Aupaluk	.	.	.	.	.	.	.	18 June (±1.1, 44)	.	23 June (±1.0, 40)
Qikirtajuaq Island	.	.	.	27 June (±0.9, 10)	29 June (±1.1, 10)	17 June (±0.7, 34)	10 July (±2.0, 17)	17 June (±3.9, 8)	6 July (±1.5, 12)	22 June (±1.4, 15)
Cape Naujaat	.	.	.	.	.	24 June (±0.0, 1)	16 July (±2.3, 3)	.	.	.
Ragged Point	.	.	.	.	.	21 June (±1.1, 37)	2 July (±2.7, 5)	19 June (±1.3, 23)	9 July (±1.4, 5)	28 June (±1.1, 4)
Kaslac/Basalte Lakes		24 June (±1.5, 8)	21 June (±1.4, 10)	26 June (±1.7, 10)	28 June (±0.7, 9)	18 June (±2.3, 3)	.	.	.	.
False River	.	.	.	.	.	.	6 July (±2.2, 12)	.	.	.
Dry Bay	.	.	.	.	.	.	5 July (±1.6, 29)	19 June (±2.7, 6)	.	25 June (±2.3, 9)
Tasker Point	29 June (±1.3, 12)	22 June (±1.2, 11)	21 June (±2.2, 9)	21 June (±2.6, 8)	30 June (±1.0, 5)	.	.	.	.	.
Big Island	.	.	21 June (±0.8, 36)	23 June (±0.7, 63)	28 June (±0.4, 48)	19 June (±0.7, 67)	13 July (±1.2, 71)	19 June (±1.7, 72)	4 July (±1.2, 10)	24 June (±2.1, 14)

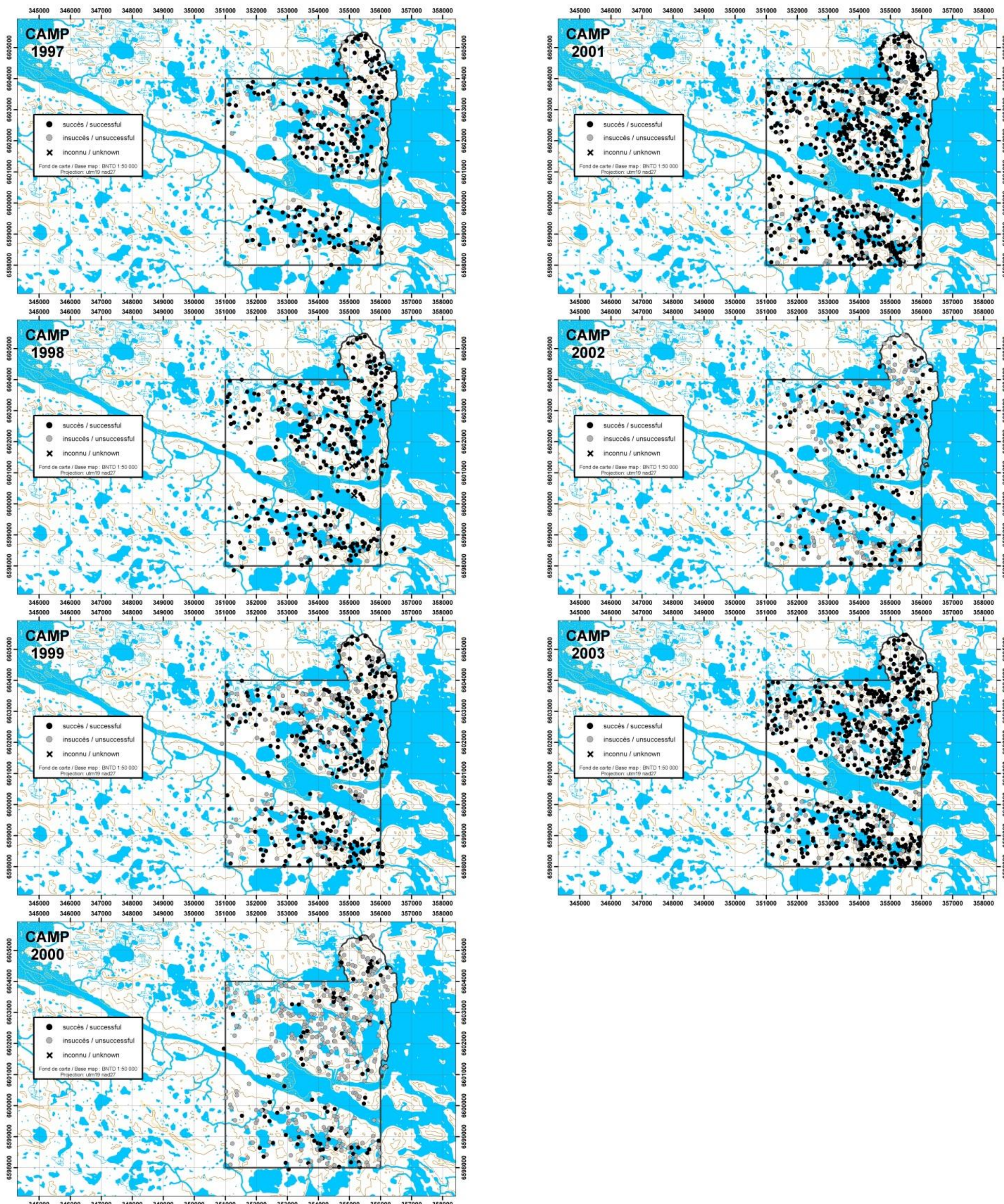
[1] Sites listed north to south.

Appendix 9-B. Mean annual hatching date (± SE, n) of Canada Geese on the secondary study sites along Ungava Bay in northern Quebec, 2006–2011.

Site [1]	2006	2007	2008	2009	2010	2011	Long-term average [2] 1996–2011
Tryon Plateau	21 June (±1.2, 12)	10 July (±1.4, 14)	.	5 July (±0.8, 14)	25 June (±1.0, 18)	.	29 June (±1.0, 73)
Aupaluk	20 June (±1.2, 17)	11 July (±1.6, 18)	23 June (±0.9, 38)	5 July (±0.9, 19)	27 June (±0.7, 34)	28 June (±0.8, 24)	25 June (±0.6, 234)
Qikirtajuaq Island	21 June (±1.5, 7)	11 July (±1.7, 12)	20 June (±1.0, 14)	28 June (±3.5, 9)	26 June (±2.2, 3)	.	26 June (±0.9, 151)
Cape Naujaat	.	.	.	.	.	.	11 July (±5.8, 4)
Ragged Point	15 June (±0.3, 2)	.	.	.	.	.	22 June (±1.0, 76)
Kaslac/Basalte Lakes	.	.	.	.	.	.	24 June (±0.8, 40)
False River	.	.	.	.	.	.	6 July (±2.2, 12)
Dry Bay	20 June (±1.2, 4)	11 July (±2.2, 3)	21 June (±2.2, 8)	1 July (±0.8, 3)	.	.	29 June (±1.3, 62)
Tasker Point	.	.	.	.	.	.	25 June (±1.0, 45)
Big Island	22 June (±3.3, 5)	7 July (±0.0, 1)	30 June (±3.2, 5)	3 July (±1.5, 10)	. [3]	.	26 June (±0.6, 402)

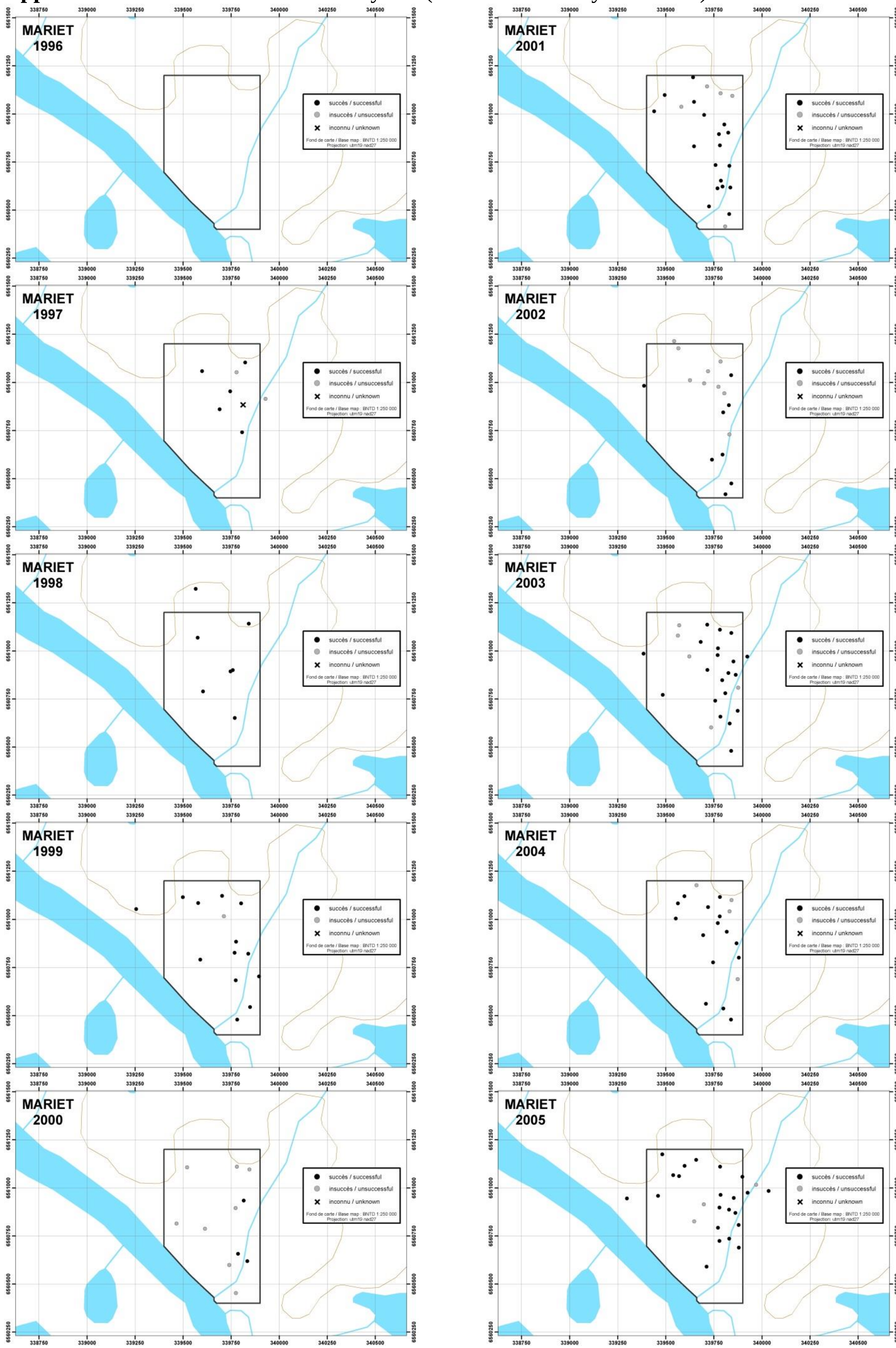
[1] Sites listed north to south.
[2] Pooling nests from all years.
[3] Search abandoned after finding only two depredated nests and because of the presence of Black Bears
.

Appendix 10. Annual maps of primary study area (CAMP) with locations of Canada Goose nests, 1997-2003

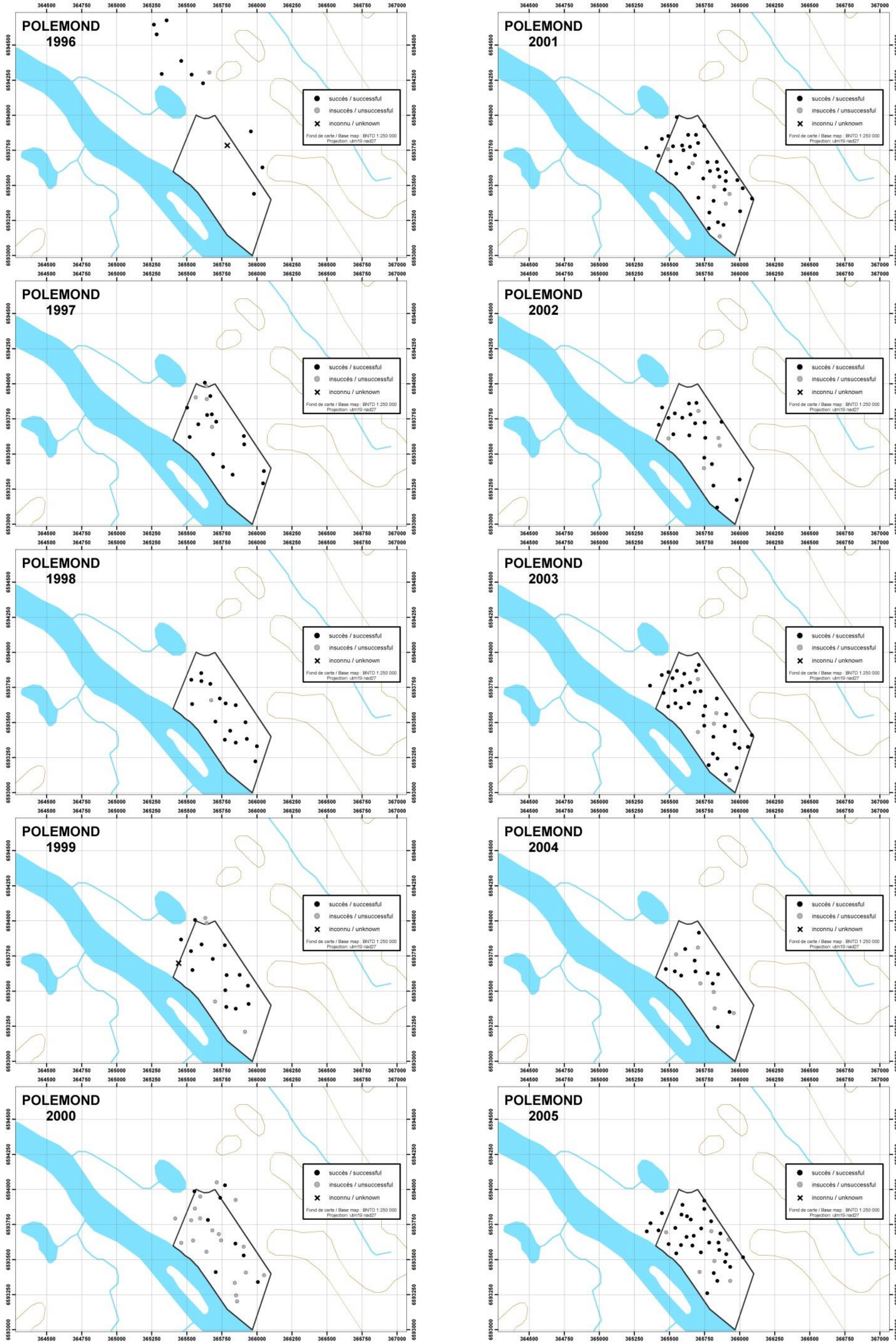


Appendix 11. Annual maps of each Hudson Bay secondary site with locations of Canada Goose nests, 1996–2005

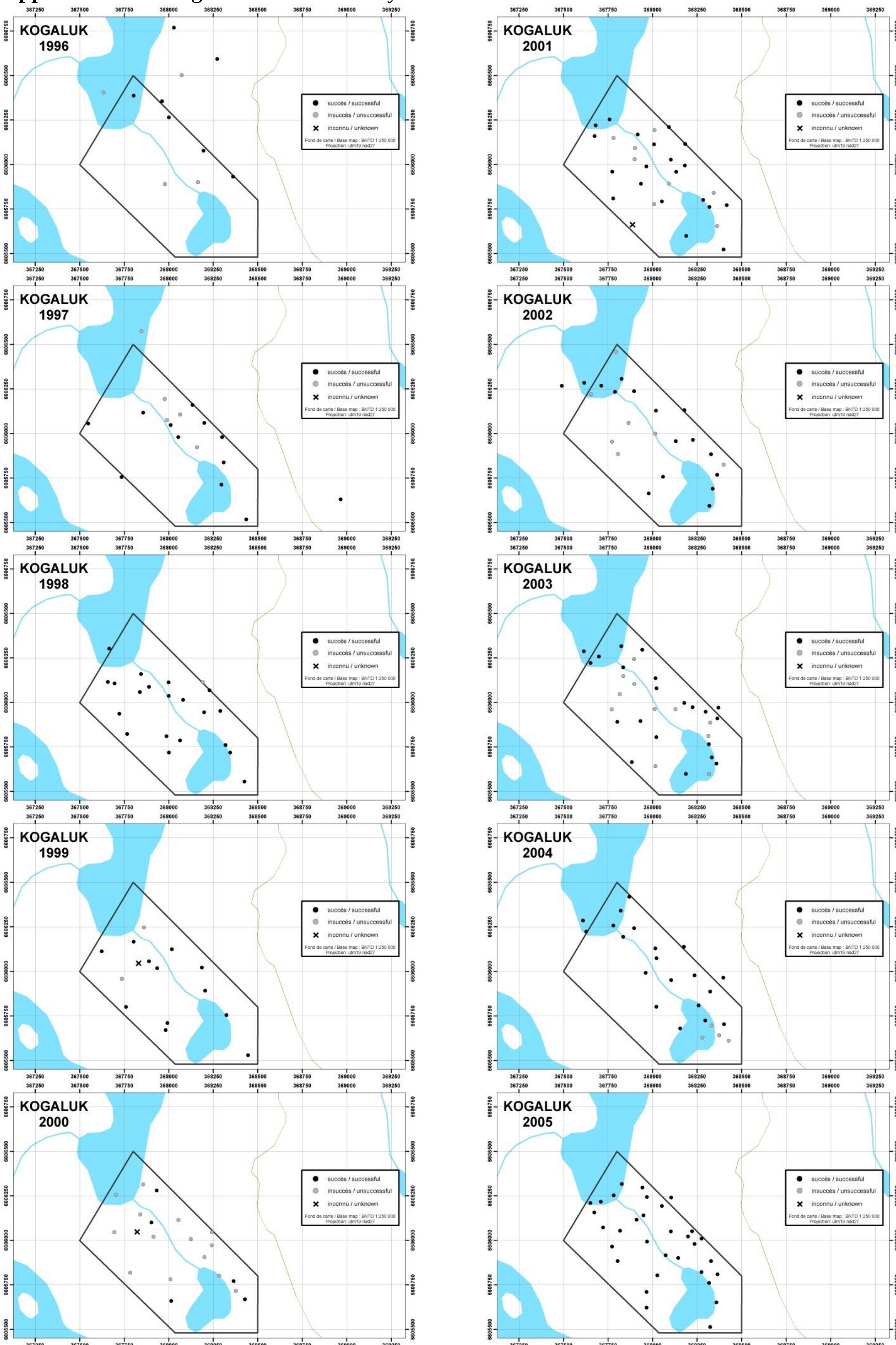
Appendix 11-A. Mariet River secondary site.(NOTE: not surveyed in 1996)



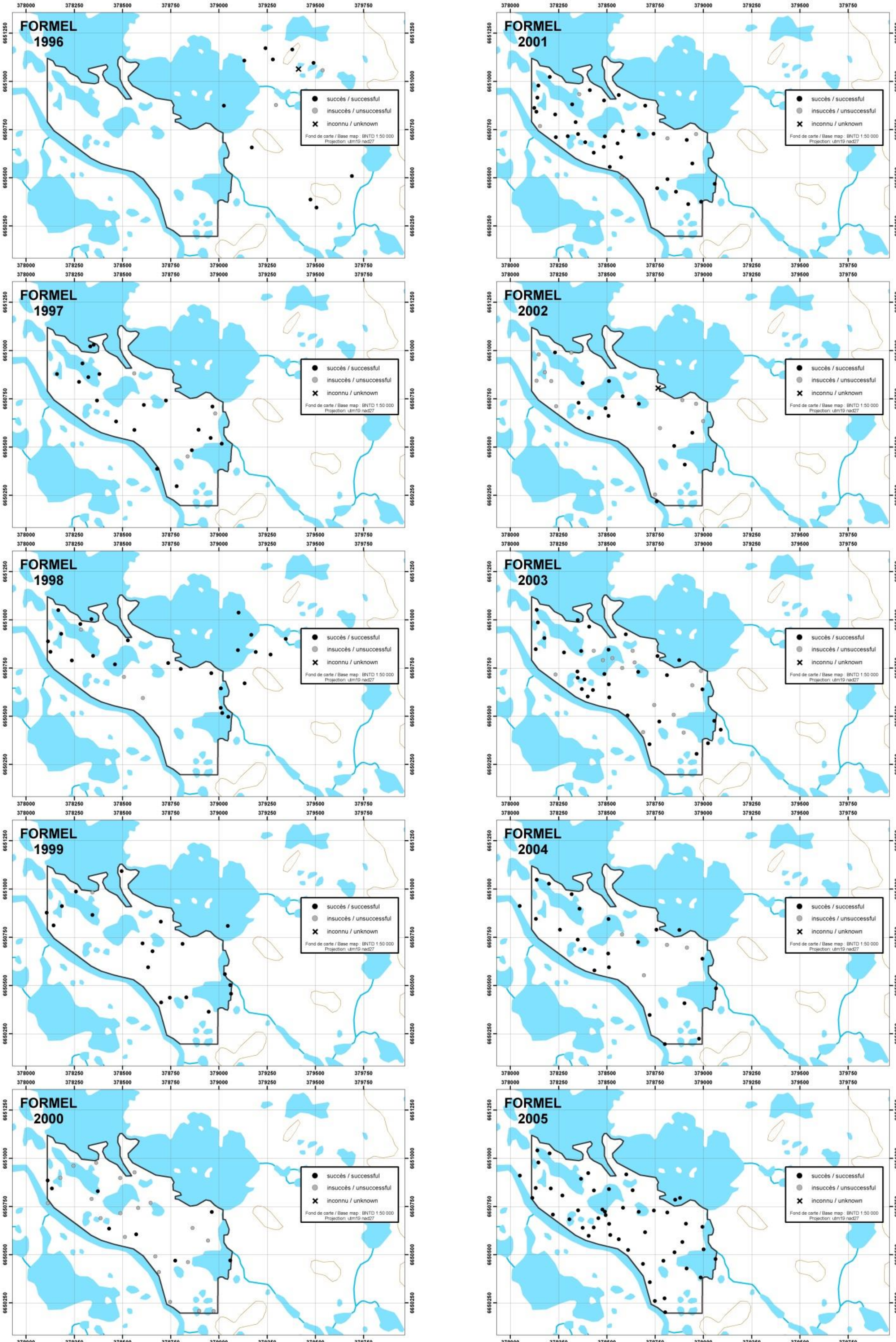
Appendix 11-B. Polemond River secondary site.



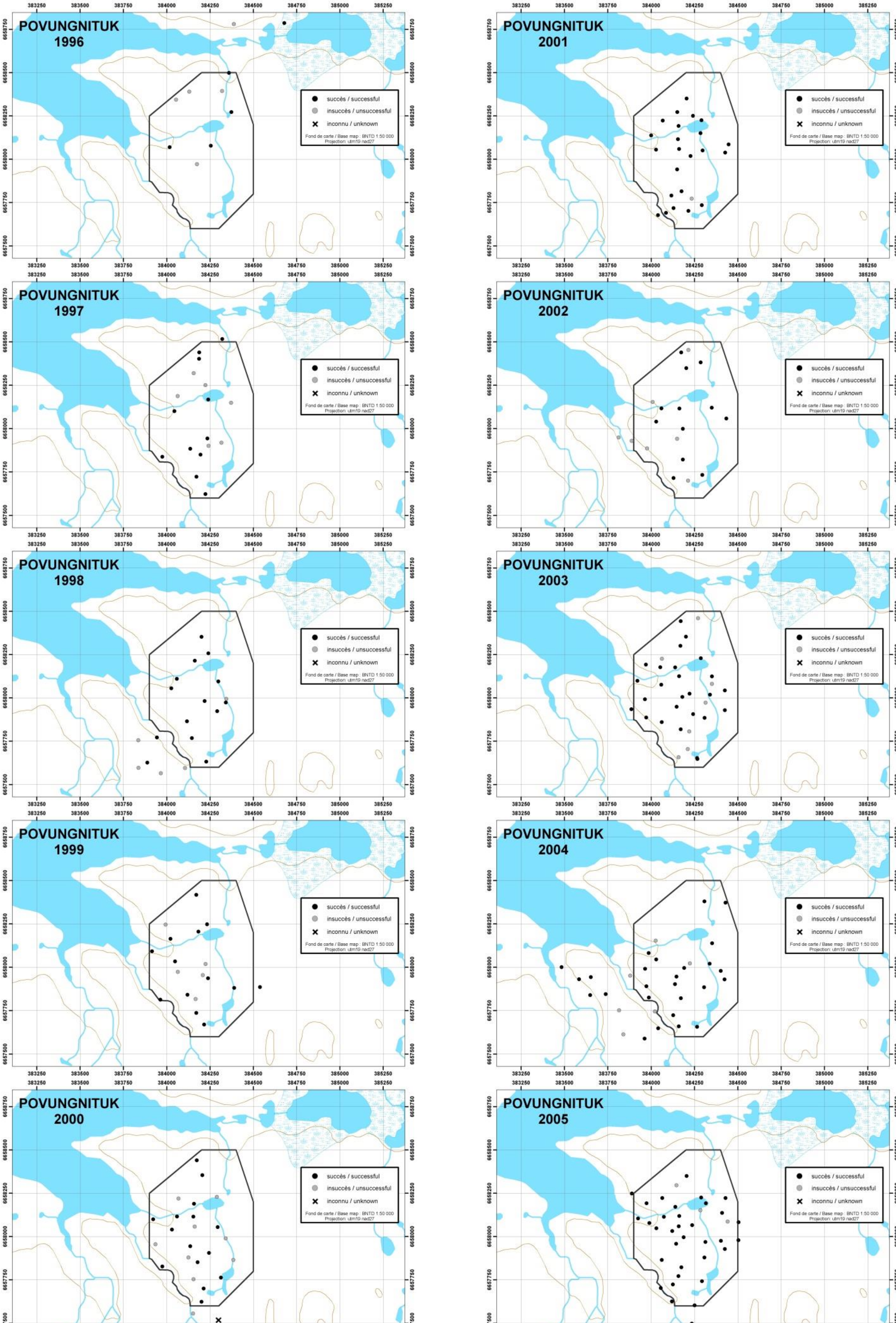
Appendix 11-C. Kogaluk River secondary site.



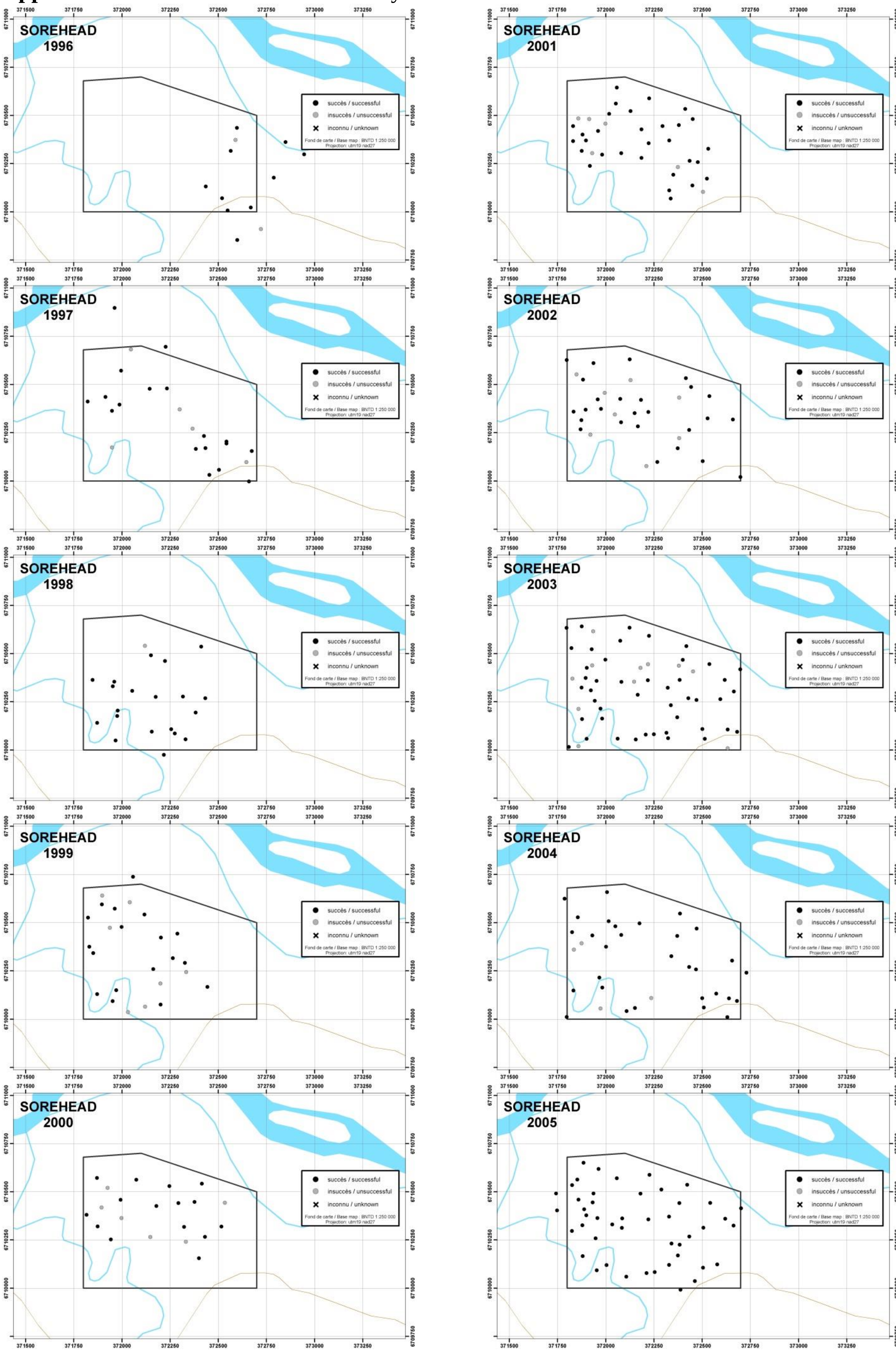
Appendix 11-D. Formel River secondary site.



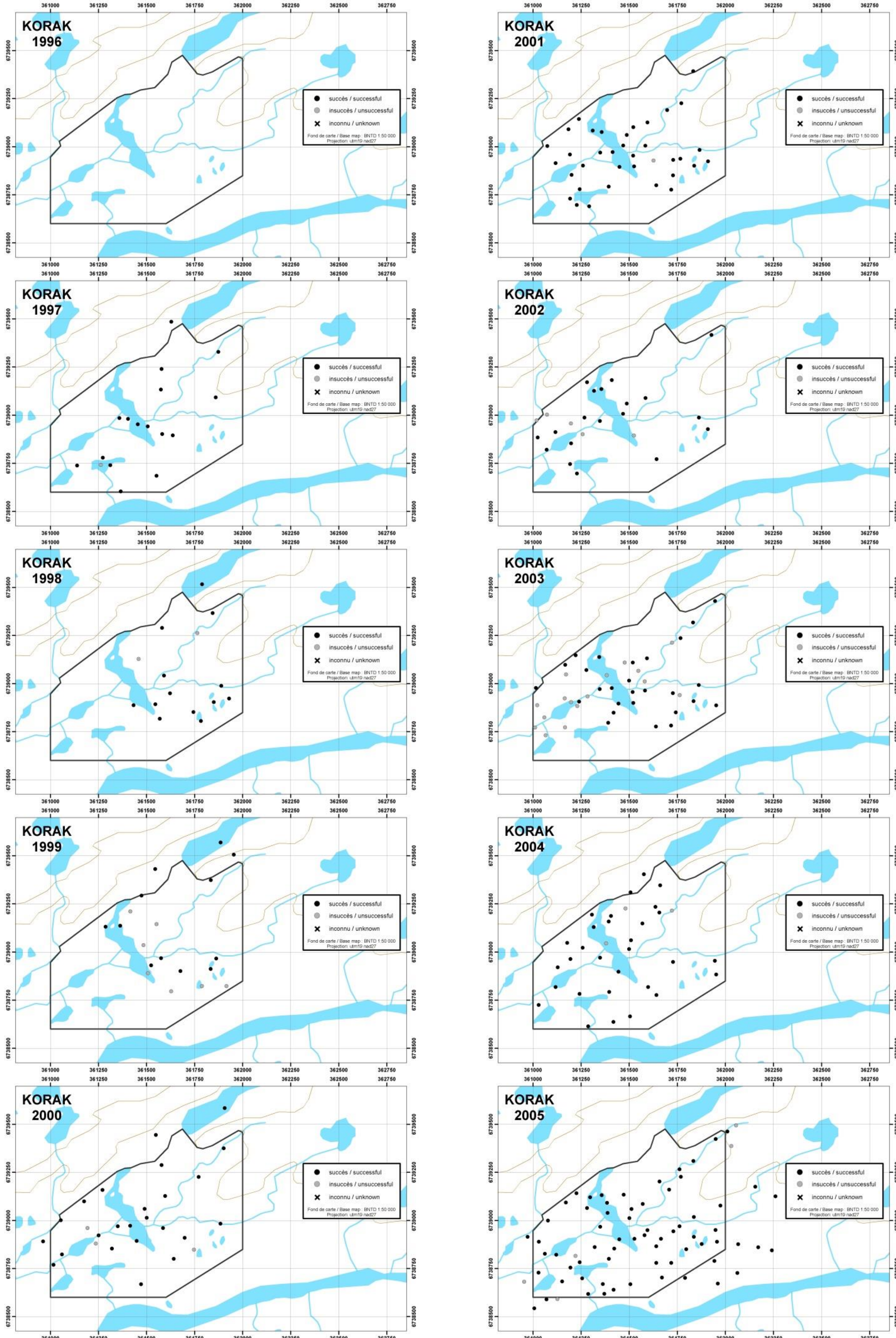
Appendix 11-E. Povungnituk Lake secondary site.



Appendix 11-F. Sorehead River secondary site.



Appendix 11-G. Korak River secondary site. (NOTE: not surveyed in 1996)



Appendix 12. Annual nest density (number of nests/km^2) and, in parentheses, number of nests found and area (km^2) searched, for Canada Geese on the secondary study sites along Hudson Bay in northern Quebec, 1996–2005.

Site[1]	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Long-term average[2] 1996–2005
Korak River	.	26.8 (17, 0.6354)	23.6 (15, 0.6354)	29.9 (19, 0.6354)	42.5 (27, 0.6354)	56.7 (36, 0.6354)	37.8 (24, 0.6354)	67.7 (43, 0.6354)	51.9 (33, 0.6354)	111.7 (71, 0.6354)	49.8 (9, 285)
Sorehead River	21.2 (12, 0.5670)	38.8 (22, 0.5670)	37.0 (21, 0.5670)	44.1 (25, 0.5670)	37.0 (21, 0.5670)	63.5 (36, 0.5670)	60.0 (34, 0.5670)	98.8 (56, 0.5670)	60.0 (34, 0.5670)	81.1 (46, 0.5670)	54.1 (10, 307)
Povungnituk Lake	23.3 (10, 0.4297)	39.6 (17, 0.4297)	44.2 (19, 0.4297)	41.9 (18, 0.4297)	58.2 (25, 0.4297)	55.9 (24, 0.4297)	44.2 (19, 0.4297)	76.8 (33, 0.4297)	74.5 (32, 0.4297)	86.1 (37, 0.4297)	54.5 (10, 234)
Formel River	29.1 (13, 0.4461)	51.6 (23, 0.4461)	60.5 (27, 0.4461)	44.8 (20, 0.4461)	62.8 (28, 0.4461)	85.2 (38, 0.4461)	56.0 (25, 0.4461)	98.6 (44, 0.4461)	58.3 (26, 0.4461)	109.8 (49, 0.4461)	65.7 (10, 293)
Kogaluk River	19.7 (11, 0.5597)	30.4 (17, 0.5597)	37.5 (21, 0.5597)	26.8 (15, 0.5597)	35.7 (20, 0.5597)	51.8 (29, 0.5597)	41.1 (23, 0.5597)	57.2 (32, 0.5597)	42.9 (24, 0.5597)	57.2 (32, 0.5597)	40.0 (10, 224)
Polemond River	34.5 (12, 0.3482)	54.6 (19, 0.3482)	48.8 (17, 0.3482)	54.6 (19, 0.3482)	77.5 (27, 0.3482)	120.6 (42, 0.3482)	71.8 (25, 0.3482)	114.9 (40, 0.3482)	51.7 (18, 0.3482)	106.3 (37, 0.3482)	73.5 (10, 256)
Mariet River	.	22.3 (8, 0.3586)	19.5 (7, 0.3586)	39.0 (14, 0.3586)	30.7 (11, 0.3586)	64.1 (23, 0.3586)	47.4 (17, 0.3586)	69.7 (25, 0.3586)	55.8 (20, 0.3586)	69.7 (25, 0.3586)	46.5 (9, 150)

[1] Sites listed north to south.
[2] Average of the annual nest densities; the number of years the site was surveyed and the total number of nests found (all years combined) in parentheses.

Appendix 13-A. Annual nest density (number of nests/km^2) and, in parentheses, number of nests found and area (km^2) searched, for Canada Geese on the secondary study sites along Ungava Bay in northern Quebec, 1996–2005.

Site [1]	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Tryon Plateau	.	.	.	.	.	.	.	28.0 (41*, 1.4273)	.	.
Aupaluk	.	.	.	.	.	.	.	34.1 (47*, 1.3508)	.	73.2 (47, 0.6422)
Qikirtajuaq Island	.	.	.	112.4 (12, 0.1068)	66.8 (10, 0.1498)	53.7 (38, 0.7077)	30.2 (19*, 0.5625)	13.8 (13*, 0.7230)	26.2 (16, 0.6097)	41.4 (16, 0.3861)
Cape Naujaat	.	.	.	.	.	42.4 (14, 0.3300)	.[2] (4, –)	.	.	.
Ragged Point	.	.	.	.	.	44.1 (41, 0.9300)	6.7 (14, 2.0759)	6.7 (27, 4.0305)	17.1 (11, 0.6444)	28.4 (15, 0.5279)
Kaslac/Basalte Lakes	.	24.2 (11, 0.4540)	42.2 (12, 0.2843)	114.2 (15, 0.1314)	42.0 (9, 0.2142)	33.4 (6, 0.1794)	.	.	.	.
False River	.	.	.	.	.	.	18.1 (27, 1.4900)	.	.	.
Dry Bay	.	.	.	.	.	.	16.5 (33, 1.9969)	11.3 (8, 0.7102)	.	48.4 (11, 0.2275)
Tasker Point	3.5 (16, 4.5900)	4.2 (17, 4.0448)	9.0 (11, 1.2272)	9.2 (12, 1.3059)	6.2 (7, 1.1276)	.	.	.	.	.
Big Island	.	.	12.4 (38, 3.0751)	32.6 (74, 2.2709)	38.4 (54, 1.4049)	29.8 (82, 2.7471)	25.6 (88*, 3.1258)	20.8 (89*, 3.6063)	30.1 (32, 1.0636)	24.9 (27, 1.0839)

[1] Sites listed north to south.
[2] Too few active nests to calculate density.
* Not all nests used to calculate density (usually due to coordinates of some nests not recorded or some nests located outside of study area).

Appendix 13-B. Annual nest density (number of nests/km^2) and, in parentheses, number of nests found and area (km^2) searched, for Canada Geese on the secondary study sites along Ungava Bay in northern Quebec, 2006–2011.

Site[1]	2006	2007	2008	2009	2010	2011	Long-term average[2] 1996–2011
Tryon Plateau	30.7 (28, 0.9132)	28.5 (16, 0.5621)	.	33.3 (15, 0.4505)	21.5 (18, 0.8379)	.	28.4 (0.8382, 5, 117)
Aupaluk	47.6 (40, 0.8404)	23.4 (22, 0.9422)	49.2 (40, 0.8134)	28.7 (22, 0.7675)	35.8 (34, 0.9485)	34.6 (25, 0.7217)	40.8 (0.8783, 8, 276)
Qikirtajuaq Island	32.4 (19*, 0.2777)	19.0 (14, 0.7386)	28.5 (18, 0.6316)	28.4 (11, 0.3877)	23.8 (4, 0.1684)	.	39.7 (0.4541, 12, 175)
Cape Naujaat	.	.	.	.	.	.	42.2 (0.3300, 2, 18)
Ragged Point	21.6 (11, 0.5083)	.	.	.	.	.	20.8 (1.4528, 6, 119)
Kaslac/Basalte Lakes	.	.	.	.	.	.	51.2 (0.2527, 5, 53)
False River	.	.	.	.	.	.	18.1 (1.4900, 1, 27)
Dry Bay	21.9 (8*, 0.3199)	82.1 (5, 0.0609)	17.0 (8*, 0.4117)	31.0 (3, 0.0968)	.	.	32.6 (0.5463, 7, 74)
Tasker Point	.	.	.	.	.	.	6.4 (2.4591, 5, 63)
Big Island	50.6 (20*, 0.1975)	9.9 (7, 0.7061)	6.8 (9*, 0.7390)	47.0 (11*, 0.1491)	.[3] (2, –)	.	27.4 (1.6808, 13, 493)

[1] Sites listed north to south.
[2] Average of the annual nest densities; the average of the area searched (km^2) each year, the number of years the site was surveyed, and the total number of nests found (all years combined) in parentheses.
[3] Search abandoned after finding only two depredated nests and because of the presence of Black Bears.
[*] Not all nests used to calculate density (usually due to coordinates of some nests not recorded or some nests located outside of study area).

Appendix 14. Percentage (number of nests in parentheses) of Canada Goose nests found per habitat type at the primary and secondary study sites (nests from all sites and years pooled) along Hudson Bay and Ungava Bay in northern Quebec, 1997–2003.

	Hummock	None	Pool	Pond	Lake	Stream	River	Unknown	ALL
Primary study area									
Mainland	3.5	24.7	13.9	13.9	29.0	5.4	8.3	1.5	100.0
	(n=13)	(n=92)	(n=52)	(n=52)	(n=108)	(n=20)	(n=31)	(n=5)	(n=373)
Wet meadow	86.1	13.7	0.0	0.0	0.0	0.2	0.0	0.0	100.0
	(n=547)	(n=87)	(n=0)	(n=0)	(n=0)	(n=1)	(n=0)	(n=0)	(n=635)
Peninsula	0.0	0.0	0.0	46.3	43.9	0.0	9.8	0.0	100.0
	(n=0)	(n=0)	(n=0)	(n=19)	(n=18)	(n=0)	(n=4)	(n=0)	(n=41)
Shoreline	0.0	0.0	0.0	42.0	48.9	7.6	1.5	0.0	100.0
	(n=0)	(n=0)	(n=0)	(n=732)	(n=851)	(n=132)	(n=27)	(n=0)	(n=1742)
Island	0.0	0.0	0.0	64.1	28.3	0.3	7.2	0.0	100.0
	(n=0)	(n=0)	(n=0)	(n=186)	(n=82)	(n=1)	(n=21)	(n=0)	(n=290)
Unknown	75.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	100.0
	(n=3)	(n=0)	(n=0)	(n=0)	(n=0)	(n=0)	(n=0)	(n=1)	(n=4)
Hudson Bay secondary sites									
Mainland	7.1	13.1	27.4	29.8	10.7	9.5	2.4	0.0	100.0
	(n=6)	(n=11)	(n=23)	(n=25)	(n=9)	(n=8)	(n=2)	(n=0)	(n=84)
Wet meadow	89.1	10.9	0.0	0.0	0.0	0.0	0.0	0.0	100.0
	(n=82)	(n=10)	(n=0)	(n=0)	(n=0)	(n=0)	(n=0)	(n=0)	(n=92)
Peninsula	0.0	0.0	0.0	77.8	22.2	0.0	0.0	0.0	100.0
	(n=0)	(n=0)	(n=0)	(n=7)	(n=2)	(n=0)	(n=0)	(n=0)	(n=9)
Shoreline	0.0	0.0	0.0	80.6	12.0	7.1	0.3	0.0	100.0
	(n=0)	(n=0)	(n=0)	(n=810)	(n=121)	(n=71)	(n=3)	(n=0)	(n=1005)
Island	0.0	0.0	0.0	75.0	16.7	8.3	0.0	0.0	100.0
	(n=0)	(n=0)	(n=0)	(n=9)	(n=2)	(n=1)	(n=0)	(n=0)	(n=12)
Unknown	0.0	20.0	0.0	0.0	0.0	0.0	0.0	80.0	100.0
	(n=0)	(n=1)	(n=0)	(n=0)	(n=0)	(n=0)	(n=0)	(n=4)	(n=5)
Hudson Bay Total[1]	15.2 (n=651)	4.7 (n=201)	1.7 (n=75)	42.9 (n=1840)	27.8 (n=1193)	5.5 (n=234)	2.1 (n=88)	0.2 (n=10)	100.0 (n=4292)
Ungava Bay secondary sites									
Mainland	8.3	13.7	38.5	22.0	3.9	7.8	1.5	4.4	100.0
	(n=17)	(n=28)	(n=79)	(n=45)	(n=8)	(n=16)	(n=3)	(n=9)	(n=205)
Wet meadow	89.0	7.3	0.0	1.2	1.2	0.0	0.0	1.2	100.0
	(n=73)	(n=6)	(n=0)	(n=1)	(n=1)	(n=0)	(n=0)	(n=1)	(n=82)
Peninsula	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	100.0
	(n=0)	(n=0)	(n=0)	(n=2)	(n=2)	(n=0)	(n=0)	(n=0)	(n=4)
Shoreline	0.0	0.0	0.0	68.6	8.0	17.2	1.0	5.2	100.0
	(n=0)	(n=0)	(n=0)	(n=275)	(n=32)	(n=69)	(n=4)	(n=21)	(n=401)
Island	0.0	0.0	0.0	75.0	20.8	4.2	0.0	0.0	100.0
	(n=0)	(n=0)	(n=0)	(n=18)	(n=5)	(n=1)	(n=0)	(n=0)	(n=24)
Unknown	12.1	33.8	0.0	0.0	0.0	0.0	0.0	54.1	100.0
	(n=19)	(n=53)	(n=0)	(n=0)	(n=0)	(n=0)	(n=0)	(n=85)	(n=157)
Ungava Bay Total	12.5 (n=109)	10.0 (n=87)	9.0 (n=79)	39.1 (n=341)	5.5 (n=48)	9.9 (n=86)	0.8 (n=7)	13.3 (n=116)	100.0 (n=873)
Grand Total	14.7 (n=760)	5.6 (n=288)	3.0 (n=154)	42.2 (n=2181)	24.0 (n=1241)	6.2 (n=320)	1.8 (n=95)	2.4 (n=126)	100.0 (n=5165)

[1] Primary study area and secondary sites pooled.

Appendix 15. Descriptive habitat variables (mean ± SD; number of nests in parentheses) of Canada Goose nests found per habitat type at the primary study area and at the secondary study sites (nests from all sites and years pooled) along Hudson Bay and Ungava Bay in northern Quebec, 1997–2003.

	Hummock	None	Pool	Pond	Lake	Stream	River	Unknown	ALL
Primary study area									
Water - distance to nearest	3.3±10.0	47.7±71.0	3.8±7.4	2.9±7.3	5.8±15.2	5.8±8.4	24.7±32.2	121.0±114.3	7.4±23.7
waterbody from nest (m)	(n=555)	(n=167)	(n=52)	(n=987)	(n=1057)	(n=154)	(n=83)	(n=5)	(n=3078)
Water - area of waterbody	0.51±0.94	3.60±0.57	0.0012±0.0006	0.13±0.21	21.48±23.09	–	–	–	11.03±19.65
nearest nest (ha)	(n=4)	(n=2)	(n=52)	(n=957)	(n=1059)				(n=2074)
Water - depth of water nearest	0.10±0.08	0.09±0.05	0.11±0.09	0.14±0.08	0.17±0.12	0.13±0.12	0.19±0.15	0.10	0.14±0.10
nest (m)	(n=536)	(n=86)	(n=48)	(n=943)	(n=984)	(n=146)	(n=63)	(n=1)	(n=2807)
Water - height of bottom of nest	0.43±0.15	0.52±0.47	0.39±0.14	0.40±0.20	0.59±0.31	0.53±0.23	1.11±0.71	0.42±0.06	0.50±0.30
bowl above water (m)	(n=554)	(n=92)	(n=51)	(n=963)	(n=1036)	(n=152)	(n=67)	(n=2)	(n=2917)
Island - distance from island	–	–	–	4.7±7.9	19.2±21.0	10.0	93.3±45.7	–	14.7±28.0
(with nest) to mainland (m)				(n=174)	(n=73)	(n=1)	(n=18)		(n=266)
Island - shallowest depth between	–	–	–	0.11±0.08	0.12±0.08	–	0.93±0.47	–	0.14±0.18
island and mainland (m)				(n=146)	(n=45)		(n=6)		(n=197)
Island – area of island	–	–	–	23.4±184.7	560.7±1075.9	59.5	7382.7±5999.3	–	715.3±2549.2
with nest (m^2)				(n=184)	(n=78)	(n=1)	(n=21)		(n=284)
Hudson Bay secondary sites									
Water - distance to nearest	3.9±5.0	31.9±44.5	3.6±2.5	3.3±3.6	4.6±5.6	5.1±4.5	13.9±11.6	2.0±1.0	4.1±7.7
waterbody from nest (m)	(n=76)	(n=19)	(n=23)	(n=841)	(n=133)	(n=79)	(n=5)	(n=3)	(n=1186)
Water - area of waterbody	0.01±0.02	0.01	0.0014±0.0005	0.14±0.20	10.35±11.98	–	–	–	1.24±5.06
nearest nest (ha)	(n=3)	(n=1)	(n=23)	(n=841)	(n=106)				(n=974)
Water - depth of water nearest	0.11±0.15	0.09±0.07	0.15±0.17	0.16±0.11	0.14±0.11	0.20±0.21	0.64	0.14±0.01	0.16±0.12
nest (m)	(n=23)	(n=9)	(n=11)	(n=496)	(n=70)	(n=45)	(n=1)	(n=2)	(n=657)
Water - height of bottom of nest	0.36±0.15	0.67±0.70	0.45±0.12	0.47±0.21	0.53±0.20	0.76±0.36	0.42	0.55±0.21	0.50±0.24
bowl above water (m)	(n=26)	(n=9)	(n=12)	(n=508)	(n=82)	(n=46)	(n=1)	(n=2)	(n=686)
Island - distance from island	–	–	–	3.6±2.2	–	–	–	–	3.6±2.2
(with nest) to mainland (m)				(n=6)					(n=6)
Island - shallowest depth between	–	–	–	0.11±0.08	–	–	–	–	0.11±0.08
island and mainland (m)				(n=5)					(n=5)
Island – area of island	–	–	–	13.5±13.1	–	–	–	–	13.5±13.1
with nest (m^2)				(n=6)					(n=6)
Ungava Bay secondary sites									
Water - distance to nearest	15.3±22.7	23.5±27.4	4.0±5.8	5.9±10.1	9.6±19.4	5.8±6.7	13.9±9.7	12.1±24.4	8.2±15.3
waterbody from nest (m)	(n=16)	(n=55)	(n=76)	(n=317)	(n=42)	(n=83)	(n=7)	(n=53)	(n=649)
Water - area of waterbody	–	0.69±1.13	0.0012±0.0006	0.06±0.12	17.61±24.32	–	–	–	0.75±5.80
nearest nest (ha)		(n=3)	(n=77)	(n=233)	(n=13)				(n=326)
Water - depth of water nearest	0.17±0.13	0.22±0.18	0.19±0.13	0.19±0.15	0.18±0.11	0.21±0.27	0.91±1.41	0.19±0.18	0.20±0.22
nest (m)	(n=10)	(n=41)	(n=56)	(n=221)	(n=13)	(n=60)	(n=4)	(n=23)	(n=428)
Water - height of bottom of nest	0.69±0.69	1.07±0.72	0.39±0.24	0.50±0.32	0.73±0.41	0.68±0.67	0.65±0.74	0.43±0.19	0.59±0.50
bowl above water (m)	(n=51)	(n=41)	(n=50)	(n=215)	(n=36)	(n=53)	(n=3)	(n=22)	(n=471)
Island - distance from island	–	–	–	–	–	–	–	–	–
(with nest) to mainland (m)									
Island - shallowest depth between	–	–	–	–	–	–	–	–	–
island and mainland (m)									
Island – area of island	–	–	–	5.7±4.1	315.0±403.1	1000.0	–	–	120.9±298.3
with nest (m^2)				(n=11)	(n=2)	(n=1)			(n=14)

Appendix 16. Proportion (%) of plant species where they ranked first, second, or third most common cover-type of Canada Goose nests at the primary study area and at the secondary study sites (nests from all sites and years pooled) along Hudson Bay and Ungava Bay in northern Quebec, 1997–2003.

	Primary study area (n=3085 nests) Rank			Hudson Bay secondary sites (n=1207 nests) Rank			Ungava Bay secondary sites (n=873 nests) Rank		
Plant Species	**First**	**Second**	**Third**	**First**	**Second**	**Third**	**First**	**Second**	**Third**
Betula glandulosa (Dwarf birch)	53.5	18.5	10.4	37.8	4.4	1.4	27.7	8.9	1.9
Cassiope tetragona (Arctic white heather)	0.4	0.6	0.6	0.0	0.0	0.0	0.2	0.1	0.2
Carex spp. (Sedge)	1.1	1.6	1.8	0.2	2.0	1.9	12.6	14.8	8.7
Empetrum nigrum (Crowberry)	15.9	26.9	17.5	0.1	4.2	5.0	3.6	4.4	3.6
Eriophorum spp. (Cottongrass)	0.1	0.3	0.4	0.0	0.4	0.6	0.0	0.0	0.0
Graminae spp. (Grass)	6.8	10.2	12.5	3.1	21.1	9.7	6.6	3.2	1.5
Ledum decumbens (Labrador Tea)	11.7	19.7	17.3	0.8	3.9	6.0	5.2	7.9	4.1
Pyrola grandiflora (Wintergreen)	0.1	0.3	1.4	0.0	0.0	0.7	0.0	0.2	0.1
Rhododendron lapponicum (Lapland Rosemary)	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.6	0.2
Salix spp. (Willow)	6.0	6.7	5.8	2.2	4.6	6.2	17.4	7.7	2.3
Vaccinium uliginosum (Arctic blueberry)	0.1	0.0	0.1	0.0	0.0	0.1	0.3	0.7	0.7
Vaccinium vitis-idaea (Mountain cranberry)	4.0	13.7	25.6	0.2	3.4	7.2	1.9	5.3	5.2
Other	0.3	0.6	0.8	0.0	0.1	0.7	0.2	0.2	2.3
None recorded	0.2	1.0	5.6	55.4	55.8	60.6	23.7	46.0	69.2
Grand Total	100%	100%	100%	100%	100%	100%	100%	100%	100%

Appendix 17. Inter-annual distances (m) of nests of individual neck-collared female Canada Geese on the primary study area, 1999–2003.

Neck Collar	1999	2000	2001	2002	2003
F27A	13				
F30A	29	73	408		
F37A	47	35			
F40A	141		109		
F41A	56				
F57A			134		
F62A		71	68		
F69A		79			
F71A		18		3	
F72A		72			
F81A		167	79		
F83A		202			
F85A		133			
F91A				509	17
F93A		73	67		
F98A		68			
H0A0		230	157		
H0A2			90		81
H0A6			9		
H0A8			65		123
H0A9				11	
H1A2			95		
H1A5				18	24
H1A7					164
H2A6			122	44	7
H3A2			26		
H3A3				746	
H3A6					119
H3C2					4
H4A2					13
H4A5			127		
H4A6			194		
H4A7				76	51
H4A9				40	63
H5A6					47
H6A1				13	45
H6A2			143	141	30
H7A2				87	
H7A5				30	29
H7A8				3	
H7A9				1359	29
H7C9					42
H8C8					91
H9A5					818
H9A8					43
H9C2					82

Appendix 18. Mean annual clutch size (± SE, n) of Canada Geese on the secondary study sites along Hudson Bay in northern Quebec, 1996–2005.

Site [1]	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Long-term average [2] 1996–2005
Korak River	.	4.38 (±0.27, 16)	4.23 (±0.28, 13)	4.06 (±0.25, 17)	4.35 (±0.15, 26)	4.72 (±0.18, 36)	3.10 (±0.22, 21)	3.88 (±0.19, 40)	3.00 (±0.14, 33)	4.29 (±0.15, 66)	4.03 (±0.07, 268)
Sorehead River	3.91 (±0.41, 11)	4.95 (±0.15, 20)	4.62 (±0.25, 21)	3.96 (±0.29, 24)	4.71 (±0.27, 17)	4.66 (±0.18, 32)	3.07 (±0.19, 29)	4.53 (±0.14, 49)	3.36 (±0.16, 33)	4.59 (±0.16, 46)	4.24 (±0.07, 282)
Povungnituk Lake	3.00 (±0.39, 10)	4.40 (±0.27, 15)	5.00 (±0.24, 16)	4.13 (±0.35, 15)	3.95 (±0.25, 19)	4.79 (±0.35, 24)	3.50 (±0.33, 14)	4.13 (±0.20, 32)	3.06 (±0.19, 31)	4.44 (±0.13, 34)	4.07 (±0.09, 210)
Formel River	3.31 (±0.36, 13)	4.40 (±0.18, 20)	4.27 (±0.25, 26)	3.45 (±0.25, 20)	3.50 (±0.33, 20)	4.09 (±0.20, 34)	3.10 (±0.18, 21)	3.94 (±0.20, 36)	3.20 (±0.16, 25)	3.92 (±0.19, 49)	3.78 (±0.08, 264)
Kogaluk River	4.00 (±0.44, 9)	4.47 (±0.38, 15)	4.81 (±0.25, 21)	4.64 (±0.23, 14)	3.69 (±0.24, 16)	4.30 (±0.25, 23)	3.86 (±0.21, 21)	4.33 (±0.25, 30)	3.25 (±0.25, 20)	4.47 (±0.17, 32)	4.21 (±0.08, 201)
Polemond River	3.50 (±0.31, 12)	4.63 (±0.24, 16)	5.12 (±0.21, 17)	4.69 (±0.15, 16)	3.81 (±0.25, 21)	4.53 (±0.20, 38)	3.00 (±0.19, 23)	4.38 (±0.18, 39)	2.75 (±0.25, 16)	4.68 (±0.13, 31)	4.19 (±0.08, 229)
Mariet River	.	4.50 (±0.22, 6)	4.71 (±0.47, 7)	4.50 (±0.31, 14)	3.22 (±0.36, 9)	4.57 (±0.22, 21)	2.83 (±0.24, 12)	4.64 (±0.20, 25)	2.94 (±0.22, 18)	4.64 (±0.19, 22)	4.13 (±0.11, 134)

[1] Sites listed north to south.
[2] Pooling nests from all years.

Appendix 19-A. Mean annual clutch size (± SE, n) of Canada Geese on the secondary study sites along Ungava Bay in northern Quebec, 1996–2005.

Site[1]	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Tryon Plateau	.	.	.	.	.	.	.	4.39 (±0.26, 33)	.	.
Aupaluk	.	.	.	.	.	.	.	4.14 (±0.18, 44)	.	4.28 (±0.18, 40)
Qikirtajuaq Island	.	.	.	4.50 (±0.31, 10)	3.90 (±0.46, 10)	4.12 (±0.20, 34)	3.63 (±0.18, 16)	3.75 (±0.45, 8)	3.25 (±0.30, 12)	4.60 (±0.42, 15)
Cape Naujaat	.	.	.	.	.	5.00 (±0.00, 1)	2.00 (±0.58, 3)	.	.	.
Ragged Point	.	.	.	.	.	4.30 (±0.19, 37)	3.00 (±0.32, 5)	4.39 (±0.32, 23)	1.80 (±0.37, 5)	5.00 (±0.58, 4)
Kaslac/Basalte Lakes	.	4.36 (±0.36, 11)	4.10 (±0.50, 10)	3.70 (±0.33, 10)	3.13 (±0.40, 8)	4.00 (±1.00, 3)	.	.	.	.
False River	.	.	.	.	.	.	3.25 (±0.37, 12)	.	.	.
Dry Bay	.	.	.	.	.	.	3.90 (±0.22, 29)	4.67 (±0.71, 6)	.	3.67 (±0.47, 9)
Tasker Point	3.89 (±0.39, 9)	4.36 (±0.49, 11)	4.11 (±0.59, 9)	3.75 (±0.45, 8)	4.20 (±0.37, 5)	.	.	.	.	.
Big Island	.	.	4.28 (±0.24, 36)	4.33 (±0.17, 63)	3.68 (±0.19, 44)	3.91 (±0.18, 67)	3.39 (±0.15, 71)	4.47 (±0.17, 73)	4.06 (±0.30, 16)	4.31 (±0.43, 13)

[1] Sites listed north to south.

Appendix 19-B. Mean annual clutch size (± SE, n) of Canada Geese on the secondary study sites along Ungava Bay in northern Quebec, 2006–2011.

Site[1]	2006	2007	2008	2009	2010	2011	Long-term average[2] 1996–2011
Tryon Plateau	3.90 (±0.34, 21)	3.36 (±0.36, 14)	.	3.82 (±0.40, 11)	4.44 (±0.29, 18)	.	4.08 (±0.15, 97)
Aupaluk	4.34 (±0.19, 38)	3.05 (±0.22, 20)	4.18 (±0.23, 38)	3.58 (±0.25, 19)	3.62 (±0.20, 34)	3.40 (±0.18, 20)	3.94 (±0.08, 253)
Qikirtajuaq Island	3.91 (±0.37, 11)	3.57 (±0.23, 14)	4.86 (±0.42, 14)	3.38 (±0.26, 8)	3.33 (±0.33, 3)	.	3.99 (±0.10, 155)
Cape Naujaat	.	.	.	.	.	.	2.75 (±0.85, 4)
Ragged Point	4.29 (±0.64, 7)	.	.	.	.	.	4.12 (±0.16, 81)
Kaslac/Basalte Lakes	.	.	.	.	.	.	3.88 (±0.20, 42)
False River	.	.	.	.	.	.	3.25 (±0.37, 12)
Dry Bay	4.00 (±0.37, 6)	3.00 (±0.58, 3)	5.00 (±0.38, 8)	4.33 (±0.33, 3)	.	.	4.06 (±0.16, 64)
Tasker Point	.	.	.	.	.	.	4.07 (±0.21, 42)
Big Island	3.50 (±0.38, 8)	3.00 (±0.00, 1)	4.80 (±0.73, 5)	3.00 (±0.30, 10)	.	.	3.99 (±0.07, 407)

[1] Sites listed north to south.
[2] Pooling nests from all years.

Appendix 20. Annual apparent nesting success (%) (± SE, n) of Canada Geese on the secondary study sites along Hudson Bay in northern Quebec, 1996-2005.

Site [1]	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Long-term average [2] 1996–2005
Korak River	.	94.1 (±5.9, 17)	86.7 (±9.1, 15)	63.2 (±11.4, 19)	88.9 (±6.2, 27)	97.2 (±2.8, 36)	79.2 (±8.5, 24)	62.8 (±7.5, 43)	90.9 (±5.1, 33)	81.7 (±4.6, 71)	82.1 (±2.3, 285)
Sorehead River	83.3 (±11.2, 12)	78.3 (±8.8, 23)	95.2 (±4.8, 21)	72.0 (±9.2, 25)	71.4 (±10.1, 21)	83.3 (±6.3, 36)	76.5 (±7.4, 34)	80.4 (±5.4, 56)	88.2 (±5.6, 34)	89.1 (±4.6, 46)	82.1 (±2.2, 308)
Povungnituk Lake	50.0 (±16.7, 10)	64.7 (±11.9, 17)	73.7 (±10.4, 19)	72.2 (±10.9, 18)	60.0 (±10.0, 25)	95.8 (±4.2, 24)	63.2 (±11.4, 19)	78.8 (±7.2, 33)	81.3 (±7.0, 32)	75.7 (±7.2, 37)	73.9 (±2.9, 234)
Formel River	76.9 (±12.2, 13)	86.4 (±7.5, 22)	88.9 (±6.2, 27)	95.0 (±5.0, 20)	28.6 (±8.7, 28)	86.8 (±5.6, 38)	52.0 (±10.2, 25)	70.5 (±7.0, 44)	84.6 (±7.2, 26)	89.8 (±4.4, 49)	76.4 (±2.5, 292)
Kogaluk River	63.6 (±15.2, 11)	70.6 (±11.4, 17)	95.2 (±4.8, 21)	80.0 (±10.7, 15)	25.0 (±9.9, 20)	69.0 (±8.7, 29)	69.6 (±9.8, 23)	65.6 (±8.5, 32)	83.3 (±7.8, 24)	100.0 (±0.0, 32)	73.7 (±2.9, 224)
Polemond River	83.3 (±11.2, 12)	78.9 (±9.6, 19)	94.1 (±5.9, 17)	73.7 (±10.4, 19)	33.3 (±9.2, 27)	85.7 (±5.5, 42)	80.0 (±8.2, 25)	87.5 (±5.3, 40)	66.7 (±11.4, 18)	75.7 (±7.2, 37)	76.2 (±2.7, 256)
Mariet River	.	62.5 (±18.3, 8)	100.0 (±0.0, 7)	92.9 (±7.1, 14)	27.3 (±14.1, 11)	78.3 (±8.8, 23)	47.1 (±12.5, 17)	80.0 (±8.2, 25)	75.0 (±9.9, 20)	72.0 (±9.2, 25)	71.3 (±3.7, 150)

[1] Sites listed north to south.
[2] Pooling nests from all years.

Appendix 21-A. Annual apparent nesting success (%) (± SE, n) of Canada Geese on the secondary study sites along Ungava Bay in northern Quebec, 1996-2005.

Site [1]	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Tryon Plateau	.	.	.	.	.	.	.	61.0 (±7.7, 41)	.	.
Aupaluk	.	.	.	.	.	.	.	68.1 (±6.9, 47)	.	74.5 (±6.4, 47)
Qikirtajuaq Island	.	.	.	75.0 (±13.1, 12)	60.0 (±16.3, 10)	47.4 (±8.2, 38)	52.6 (±11.8, 19)	38.5 (±14.0, 13)	12.5 (±8.5, 16)	75.0 (±11.2, 16)
Cape Naujaat	.	.	.	.	.	0.0 (±0.0, 14)	50.0 (±28.9, 4)	.	.	.
Ragged Point	.	.	.	.	.	63.4 (±7.6, 41)	7.1 (±7.1, 14)	63.0 (±9.5, 27)	27.3 (±14.1, 11)	20.0 (±10.7, 15)
Kaslac/Basalte Lakes	.	81.8 (±12.2, 11)	75.0 (±13.1, 12)	53.3 (±13.3, 15)	66.7 (±16.7, 9)	50.0 (±22.4, 6)	.	.	.	.
False River	.	.	.	.	.	.	18.5 (±7.6, 27)	.	.	.
Dry Bay	.	.	.	.	.	.	60.6 (±8.6, 33)	62.5 (±18.3, 8)	.	54.5 (±15.7, 11)
Tasker Point	12.5 (±8.5, 16)	47.1 (±12.5, 17)	81.8 (±12.2, 11)	58.3 (±14.9, 12)	14.3 (±14.3, 7)	.	.	.	.	.
Big Island	.	.	76.3 (±7.0, 38)	59.5 (±5.7, 74)	16.7 (±5.1, 54)	52.4 (±5.5, 82)	4.5 (±2.2, 88)	66.3 (±5.0, 89)	21.9 (±7.4, 32)	37.0 (±9.5, 27)

[1] Sites listed north to south.

Appendix 21-B. Annual apparent nesting success (%) (± SE, n) of Canada Geese on the secondary study sites along Ungava Bay in northern Quebec, 2006–2011.

Site [1]	2006	2007	2008	2009	2010	2011	Long-term average [2] 1996–2011
Tryon Plateau	53.6 (±9.6, 28)	50.0 (±12.9, 16)	.	33.3 (±12.6, 15)	83.3 (±9.0, 18)	.	57.6 (±4.6, 118)
Aupaluk	70.0 (±7.3, 40)	40.9 (±10.7, 22)	60.0 (±7.8, 40)	59.1 (±10.7, 22)	79.4 (±7.0, 34)	48.0 (±10.2, 25)	65.0 (±2.9, 277)
Qikirtajuaq Island	36.8 (±11.4, 19)	21.4 (±11.4, 14)	72.2 (±10.9, 18)	27.3 (±14.1, 11)	50.0 (±28.9, 4)	.	47.4 (±3.6, 190)
Cape Naujaat	.	.	.	.	.	.	11.1 (±7.6, 18)
Ragged Point	54.5 (±15.7, 11)	.	.	.	.	.	47.1 (±4.6, 119)
Kaslac/Basalte Lakes	.	.	.	.	.	.	66.0 (±6.6, 53)
False River	.	.	.	.	.	.	18.5 (±7.6, 27)
Dry Bay	37.5 (±18.3, 8)	0.0 (±0.0, 5)	100.0 (±0.0, 8)	100.0 (±0.0, 3)	.	.	59.2 (±5.7, 76)
Tasker Point	.	.	.	.	.	.	42.9 (±6.3, 63)
Big Island	25.0 (±9.9, 20)	0.0 (±0.0, 7)	. [3]	45.5 (±15.7, 11)	.	.	41.2 (±2.2, 522)

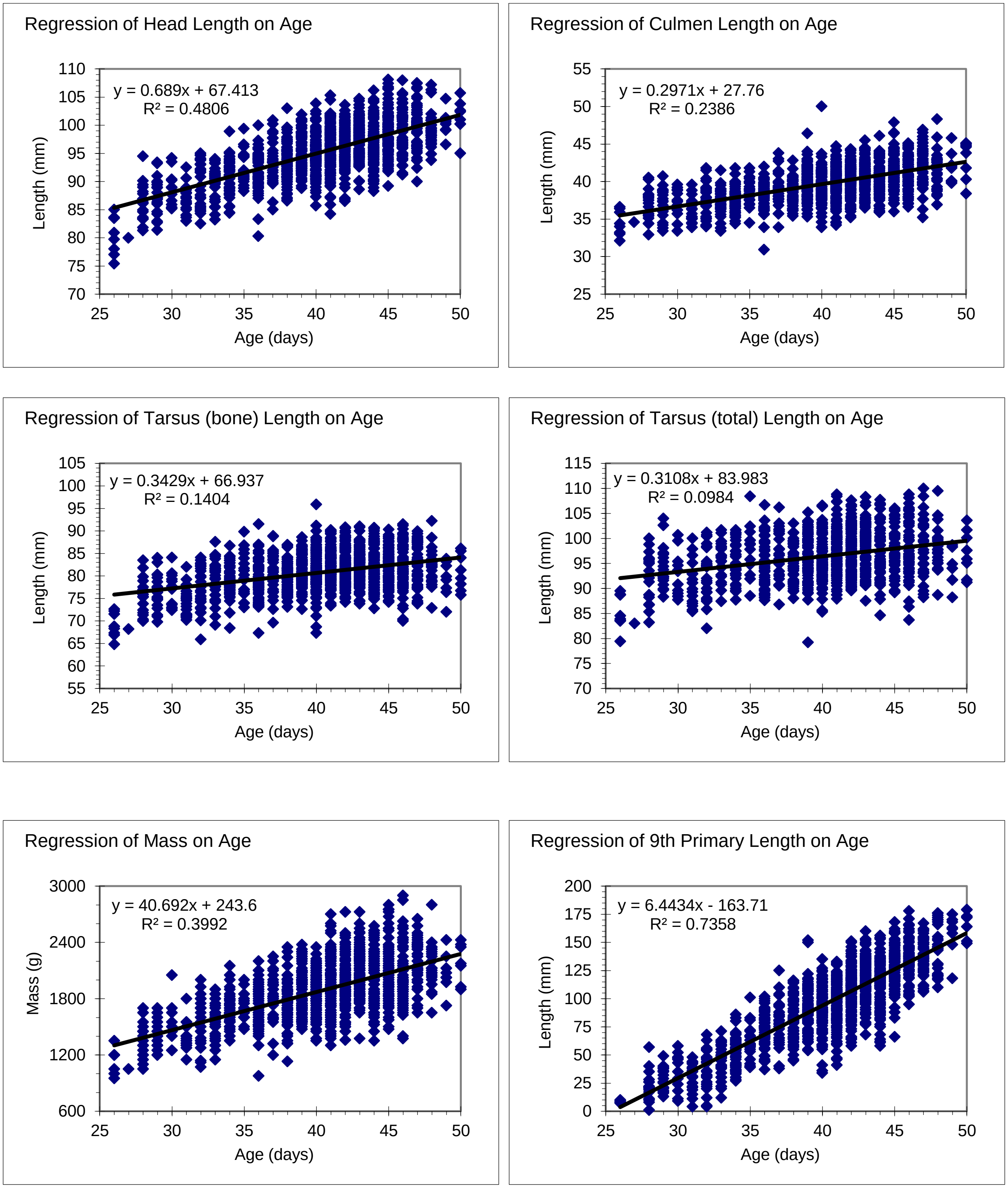
[1] Sites listed north to south.
[2] Pooling nests from all years.
[3] Due to the presence of Black Bears this site was not revisited after hatch.

Appendix 22. Mean (± SD) head, culmen, tarsus (bone), tarsus (total), mass, and nineth primary measurements of web-tagged juvenile Canada Geese, by age, at capture during banding drives on the primary study area, 1997–2003 (years pooled).

Age (days)	Number of birds measured	Head (mm)	Culmen (mm)	Tarsus-bone (mm)	Tarsus-total [1] (mm)	Mass (g)	9th primary (mm) [2]
26	8	80.4 (± 3.5)	34.5 (± 1.7)	69.1 (± 2.8)	85.2 (± 3.5, 8)	1143.8 (± 132.1)	8.4 (± 1.1, 5)
27	1	80.0 (± 0.0)	34.6 (± 0.0)	68.2 (± 0.0)	—	1050.0 (± 0.0)	—
28	18	86.4 (± 3.3)	36.7 (± 2.1)	75.4 (± 4.0)	92.1 (± 5.0, 18)	1352.8 (± 181.9)	21.9 (± 13.0, 18)
29	21	87.5 (± 3.2)	37.0 (± 2.0)	76.5 (± 3.7)	94.5 (± 4.1, 20)	1414.3 (± 150.1)	28.2 (± 9.9, 21)
30	12	88.5 (± 3.1)	37.2 (± 2.0)	76.9 (± 3.8)	92.6 (± 4.4, 12)	1516.7 (± 214.6)	35.0 (± 16.6, 12)
31	22	86.9 (± 2.4)	36.0 (± 1.6)	74.3 (± 3.2)	91.1 (± 4.4, 17)	1402.3 (± 127.2)	31.1 (± 12.0, 22)
32	28	89.8 (± 4.0)	37.3 (± 2.2)	76.8 (± 4.6)	92.9 (± 5.1, 24)	1560.2 (± 251.4)	36.9 (± 17.1, 26)
33	34	90.0 (± 2.9)	37.2 (± 1.8)	79.2 (± 4.2)	95.7 (± 3.8, 22)	1575.0 (± 180.3)	43.6 (± 14.1, 34)
34	56	90.9 (± 2.9)	37.4 (± 1.6)	79.3 (± 3.4)	95.2 (± 3.7, 37)	1656.3 (± 162.2)	50.9 (± 14.0, 56)
35	21	92.4 (± 2.9)	38.8 (± 1.8)	79.6 (± 4.7)	97.5 (± 5.0, 14)	1708.3 (± 132.8)	61.8 (± 14.9, 21)
36	59	92.0 (± 3.3)	38.4 (± 1.8)	79.5 (± 4.5)	95.0 (± 4.8, 47)	1688.2 (± 222.9)	72.6 (± 15.4, 58)
37	33	93.5 (± 3.7)	39.0 (± 2.1)	80.7 (± 4.4)	96.8 (± 4.8, 26)	1815.9 (± 224.3)	80.6 (± 19.4, 32)
38	69	93.4 (± 3.3)	38.8 (± 1.5)	79.4 (± 3.2)	95.4 (± 3.8, 48)	1748.0 (± 231.4)	81.8 (± 18.0, 69)
39	92	95.5 (± 3.2)	39.8 (± 2.0)	81.3 (± 3.5)	96.4 (± 4.6, 75)	1863.8 (± 214.9)	90.2 (± 18.9, 92)
40	114	94.9 (± 3.4)	39.4 (± 2.1)	80.8 (± 4.5)	95.9 (± 4.3, 92)	1853.4 (± 203.3)	92.5 (± 19.8, 114)
41	134	96.1 (± 3.7)	40.2 (± 4.2)	82.1 (± 3.9)	97.3 (± 4.5, 95)	1931.4 (± 272.2)	97.7 (± 19.9, 134)
42	135	96.5 (± 3.3)	40.2 (± 1.9)	81.9 (± 4.1)	97.5 (± 4.5, 113)	1961.3 (± 241.3)	108.2 (± 19.2, 135)
43	135	97.5 (± 2.9)	41.0 (± 4.0)	82.1 (± 3.5)	98.3 (± 4.1, 104)	2052.0 (± 232.7)	118.1 (± 17.8, 135)
44	100	96.5 (± 3.7)	40.2 (± 2.0)	81.6 (± 4.2)	97.4 (± 5.2, 61)	2006.9 (± 279.7)	111.2 (± 21.2, 99)
45	99	98.6 (± 3.7)	41.3 (± 2.1)	82.0 (± 3.8)	97.6 (± 4.6, 49)	2069.3 (± 296.3)	126.6 (± 18.6, 99)
46	77	98.5 (± 3.9)	41.1 (± 2.1)	82.0 (± 4.7)	97.9 (± 5.9, 50)	2078.2 (± 321.9)	136.0 (± 18.0, 77)
47	56	99.5 (± 3.8)	42.0 (± 2.5)	82.2 (± 4.4)	97.8 (± 5.6, 34)	2151.8 (± 225.9)	137.4 (± 15.3, 56)
48	29	99.7 (± 3.9)	41.5 (± 2.4)	81.8 (± 3.7)	97.9 (± 4.3, 24)	2158.6 (± 216.9)	144.4 (± 21.0, 29)
49	8	100.3 (± 2.3)	41.9 (± 2.1)	79.2 (± 4.0)	93.9 (± 3.8, 7)	2078.1 (± 204.6)	157.8 (± 18.0, 8)
50	8	101.4 (± 3.2)	43.0 (± 2.5)	80.9 (± 4.0)	97.1 (± 4.5, 8)	2185.7 (± 212.6) [3]	166.7 (± 12.5, 7)

[1] This measurement was recorded only from 1997 to 2001, thus the sample size (*n*) is given after SD.
[2] Number of birds measured for length of nineth primary is less than for other measurements, therefore *n* is given after SD.
[3] Number of birds weighed is 7 instead of 8.

Appendix 23. Regression (with linear trend line and equation) of head, culmen, tarsus (bone), tarsus (total), mass, and nineth primary on age for web-tagged juvenile Canada Geese at capture during banding drives on the primary study area, 1997–2003 (years pooled).

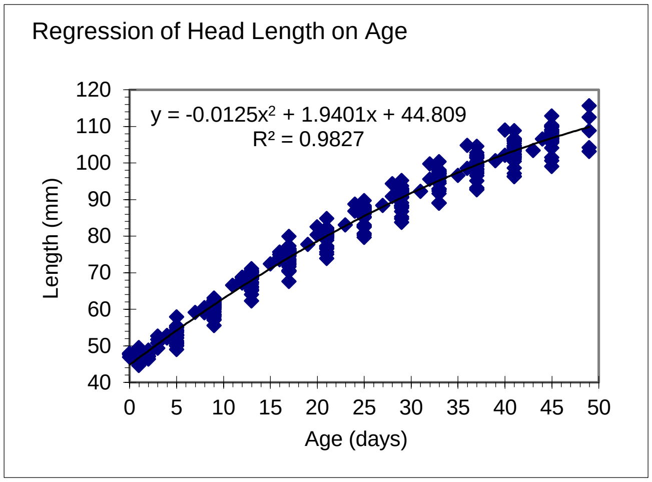


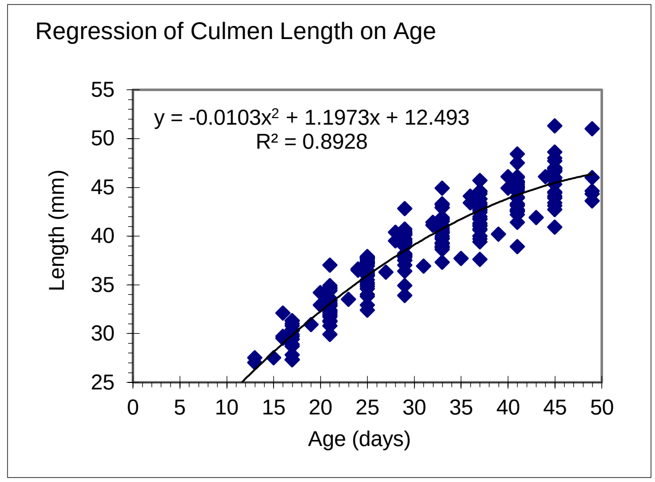
Appendix 24. Mean (± SD) head, culmen, tarsus (total), and mass, by age, of captive-fed Canada Goose goslings on the primary study area, 2003.

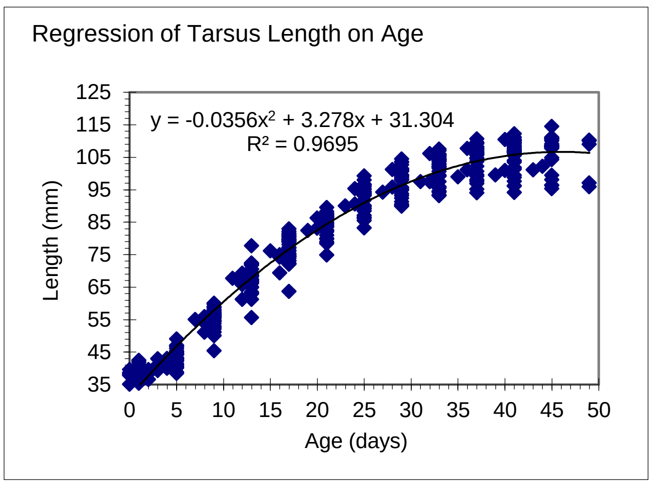
Age (days)	Number of birds measured[1]	Head (mm)	Culmen (mm)	Tarsus-total (mm)	Mass (g)
1	29	47.8 (± 1.3)	.	38.4 (± 2.1)	96.1 (± 8.2)
5	33	52.8 (± 1.9)	.	43.4 (± 2.4)	152.7 (± 25.3)
9	33	60.3 (± 1.9)	.	55.2 (± 3.1)	328.3 (± 52.4)
13	32	68.1 (± 2.1; 31)	26.5 (± 1.4, 3)	67.6 (± 4.0)	573.5 (± 73.4, 31)
17	28	74.4 (± 2.6)	29.5 (± 1.4, 18)	76.6 (± 4.1)	840.9 (± 109.7, 27)
21	28	79.6 (± 2.4)	32.9 (± 1.4)	84.3 (± 3.5)	1158.1 (± 132.8)
25	28	85.6 (± 2.6)	36.2 (± 1.6)	92.3 (± 4.1)	1550.5 (± 157.4)
29	28	90.5 (± 2.9)	38.8 (± 1.8)	97.7 (± 4.4)	1913.0 (± 227.1)
33	28	95.1 (± 2.9)	40.7 (± 1.7)	101.4 (± 4.4)	2226.3 (± 242.2)
37	28	99.2 (± 3.0)	42.2 (± 1.9)	104.2 (± 4.7)	2522.7 (± 271.8)
41	28	103.2 (± 3.2)	44.3 (± 2.0)	105.2 (± 5.1)	2760.2 (± 300.5, 27)
45	23	107.0 (± 3.3)	45.8 (± 2.2)	106.3 (± 5.4)	3042.4 (± 366.2)

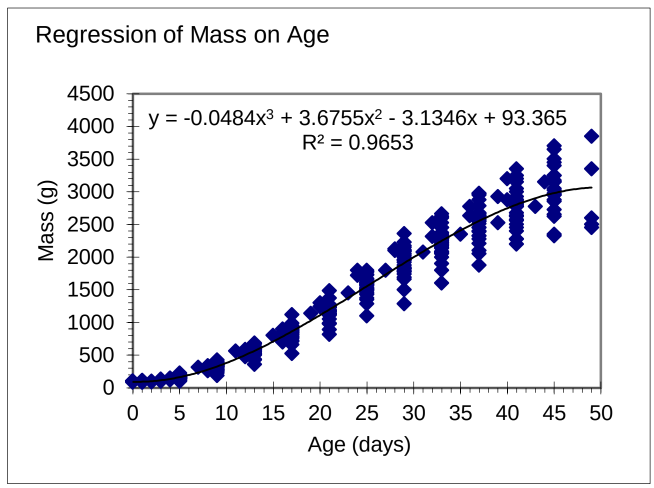
[1] If for a particular age and measurement the number of birds measured differs from this column, the *n* is provided after the SD.

Appendix 25. Regression (with polynomial trend line and equation) of head, culmen, tarsus (total), and mass on age for captive-fed Canada Goose goslings on the primary study area, 2003.









CANADA GOOSE STUDY

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Additional information can be obtained at:

Environment Canada
Inquiry Centre
10 Wellington Street, 23rd Floor
Gatineau QC K1A 0H3
Telephone: 1-800-668-6767 (in Canada only) or 819-997-2800
Fax: 819-994-1412
TTY: 819-994-0736
Email : enviroinfo@ec.gc.ca