UNIVERSITÉ DU QUÉBEC À MONTRÉAL

# EFFETS DES COLLIERS ÉMETTEURS SUR LE MAINTIEN DU COUPLE, LE SUCCÈS REPRODUCTEUR ET LE COMPORTEMENT DE LA GRANDE OIE DES NEIGES

MÉMOIRE

PRÉSENTÉ

COMME EXIGENCE PARTIELLE

DE LA MAÎTRISE EN BIOLOGIE

PAR

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NOVEMBRE 2000

## REMERCIEMENTS


Tout d'abord, je tiens à remercier mon directeur, Jean-François Giroux pour sa disponibilité, son soutien, ses nombreux et judicieux conseils, ainsi que son souci du détail et de la rigueur scientifique. Merci à mon codirecteur Gilles Gauthier pour ses conseils et suggestions ainsi qu'à Joël Bêty pour m'avoir permis d'utiliser certaines de ses données, ainsi que pour ses conseils et commentaires. Merci également à Austin Reed et Jean Ferron pour la révision du mémoire et pour leurs précieux commentaires.

J'adresse un merci tout particulier à Arnaud Béchet et Antoine Nappi, avec qui j'ai partagé les hauts et les bas de cette aventure, ainsi qu'aux autres membres du laboratoire: Émmanuel Milot et Jonathan Olson.

De Bylot à l'Isle-Verte, en passant par Baie-du-Febvre, comment oublier les moments merveilleux que j'ai passés sur le terrain avec Francis St-Pierre, Nadia Nadeau, Josée Lefèbvre, Hélène Massé, Éric Reed, Gérald Picard, Réjean Deschênes, Yanie Porlier, Stéphane Menu, Amousa, Samson et Joassi Ootoovak. Vous faites partie de mes plus précieux souvenirs. Je sourirai toujours en me souvenant des durs réveils à 3h30am, du "scaneur" non-branché, du suivi "cowboy" des radios sur les routes de gravier, de la fondue de canard, du party de Bylot, et d'une aquarelle d'Arnaud.

Merci aussi à mes parents pour leurs encouragements, leur soutien indéfectible, leur confiance totale et surtout leur affection.

Finalement, je tiens à remercier les organismes suivants, car sans leur soutien, un tel projet ne pourrait avoir eu lieu: Arctic Goose Joint Venture, Polar Shelf Continental Project, les Fonds FCAR, le Hunter and Trapper Organization de Pond Inlet pour leur permission de travailler à l'Ile Bylot, le Service Canadien de la Faune, le Ministère des Affaires indiennes et du Nord canadien, l'Université Laval et l'Université du Québec à Montréal.

## AVANT-PROPOS

Ce mémoire comprend un article et une note qui seront soumis à des revues scientifiques. J'ai participé à l'essentiel de la récolte des données et à la totalité de la rédaction des deux articles. Je serai premier auteur de l'article et de la note. Jean-François Giroux, mon directeur, Gilles Gauthier, co-directeur ainsi que Joël Bêty, étudiant au doctorat à l'Université Laval nous ayant donné accès à certaines données, seront co-auteurs.

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## RÉSUMÉ

La télémétrie a joué un rôle important dans les études en écologie animale, particulièrement chez la sauvagine. Elle a été employée pour étudier l'utilisation de l'habitat, la survie et la mortalité due à la chasse et la chronologie de migration. Il existe une certaine controverse quant à l'effet des colliers émetteurs sur le comportement des oiseaux. Certains chercheurs n'ont pas trouvé d'effets négatifs alors que d'autres ont clairement établi que les radio-émetteurs affectaient le comportement ainsi que la condition des oiseaux. Les objectifs du premier chapitre sont de déterminer si les techniques de marquage et de capture utilisées ont des effets négatifs sur le maintien des couples, sur le succès reproducteur et sur le comportement de la grande oie des neiges. Les objectifs du deuxième chapitre sont de comparer la chronologie de migration ainsi que le succès reproducteur des femelles munies de radio-émetteur en couple avec leur mâle original comparativement à celles pairées avec un nouveau partenaire et de déterminer la chronologie de ré-appariement des femelles séparées de leur partenaire original. De 1995 à 1998, nous avons marqué 230 femelles avec des radio-émetteurs durant la mue des adultes sur l'île Bylot (Nunavut). Nous avons par la suite obtenu des données sur 159 de ces femelles. Les radios équipés d'une antenne de 15-cm de long orientée vers le bas, étaient fixés sur des colliers de plastique. La masse totale des colliers émetteurs représente 59±9g ou 2,5±0,02% de la masse corporelle des femelles. Dix mois après le marquage, 36% (95% IC = 27-46) des femelles étaient séparées de leur mâle original. Tenant compte de la mortalité attendue des mâles, les taux de divorce calculés étaient de 25% (95% IC = 12-38). En comparaison, les femelles munies de colliers conventionnels (sans radio) présentaient un taux de séparation de 18% (95% IC = 11-25) et un taux de divorce de 4% (95% IC = 0-16). Les colliers émetteurs provoquent des modifications comportementales entraînant des divorces ainsi qu'une diminution du succès reproducteur. Les modifications comportementales associées à la présence du collier émetteur sont plus prononcées durant le premier automne et semblent diminuer avec le temps. Par contre, deux ans après le marquage, la reproduction semble toujours négativement affectée par la présence des colliers munis de radio-émetteurs. Les femelles portant des colliers émetteurs ne démontrent pas de délais de migration et présentent des paramètres de reproduction similaires, qu'elles soient pairées avec leur mâle original ou avec un nouveau partenaire. Pris séparément, les paramètres de reproduction ne diffèrent pas statistiquement entre les deux groupes, mais sont toujours légèrement meilleurs chez les femelles pairées avec leur mâle original. Le cumul de ces effets pourrait conduire à une diminution du «fitness» des femelles en couple avec un nouveau partenaire. Nous recommandons tout d'abord de diminuer le poids des colliers munis de radio-émetteur à moins de 2,5% de la masse corporelle des oiseaux et de réduire la longueur des antennes. Un compromis doit donc être fait entre les effets que le marqueur (radio-émetteur) a sur l'oiseau et sa performance en terme de longévité (poids de la batterie) et de portée (longueur de l'antenne).



Mots clés: Radio-émetteurs, colliers, télémétrie, comportement, reproduction, grande oie des neiges

# INTRODUCTION GÉNÉRALE

Plus de 90% des espèces d'oiseaux sont monogames (Lack 1968). Il est aussi généralement accepté que l'Oie des neiges (*Chen caerulenscens*), comme toutes les autres espèces d'Ansérinés, est fidèle à son partenaire et unie pour la vie (Cooke et Sulzbach 1978). La monogamie est associée aux espèces à grande longévité, qui ont peu d'opportunité de nicher plus d'une fois à l'intérieur d'une saison de reproduction et dont les deux partenaires prodiguent des soins aux jeunes (Oring et Sayler 1992).

Lors d'une étude préliminaire en 1995 sur la Grande Oie des neiges (*Chen caerulescens atlantica*), Giroux (données non publiées) a observé des taux de séparation et de divorce nettement plus élevés que ceux relevés dans la littérature pour d'autres espèces d'Ansérinés (Forslund et Larsson 1992, Owen *et al.* 1988, Prevett et MacInnes 1980). Une séparation se définit par la perte du partenaire, qui peut être le résultat de la mortalité de ce dernier ou d'un divorce (partenaire toujours vivant). Les divorces, quant à eux, peuvent découler d'une stratégie, être accidentels (dérangements) ou encore être attribués aux activités des chercheurs (colliers émetteurs et/ou captures).

Choudhury (1995) et Ens *et al.* (1993) ont exposé plusieurs hypothèses pour expliquer que le divorce chez les oies peut être une stratégie. Premièrement, il y a l'hypothèse de l'incompatibilité, pour laquelle la séparation du couple est une décision mutuelle. Deuxièmement, il y a l'hypothèse de la meilleure option, qui survient lorsqu'un des partenaires a la possibilité d'augmenter son «fitness» en trouvant un partenaire de meilleure qualité. En effet, Ens *et al.* (1993) prétendent qu'un individu devrait engendrer un divorce uniquement lorsque les bénéfices attendus l'emportent sur les coûts envisagés. Il y a aussi l'hypothèse des erreurs dans le choix initial du partenaire, qui englobe en quelque sorte l'hypothèse de l'incompatibilité et celle de la meilleure option. Finalement, on retrouve l'hypothèse du divorce forcé, souvent engendré par l'intrusion d'un troisième individu dans le couple.

Certains divorces pourraient toutefois être attribués aux techniques utilisées par les chercheurs. Durant les trois dernières décennies, la télémétrie a joué un rôle important en écologie animale, particulièrement chez la sauvagine. Elle a été employée pour étudier l'utilisation de l'habitat (Giroux et Patterson 1995, Hughes *et al.* 1994, Petrie et Rogers 1997), la survie et la mortalité due à la chasse (Ball *et al.* 1975, Eberhardt *et al.* 1989, Schultz *et al.* 1988), la chronologie de migration (Reed *et al.* 1989, Petrie et Rogers 1997) et les routes de migration (Blouin *et al.* 1999). La plupart de chercheurs assument que les captures, les manipulations ainsi que les marqueurs (harnais, colliers conventionnels, colliers radio-émetteur) n'affectent pas les oiseaux. Cependant, si l'un ou plusieurs de ces agents de stress (captures, manipulations ou radio-émetteurs) ont des effets négatifs sur les individus étudiés, les résultats de ces études peuvent être biaisés.

Tout d'abord, il faut capturer un animal pour lui installer un marqueur. Chez les oies et bernaches, une technique de capture couramment employée consiste à entourer un groupe d'oiseaux en mue et à les diriger vers un enclos (Owen 1980). Le temps que passent les oies dans l'enclos (de 3 à 5 heures, selon la taille des captures), peut rendre les captures massives stressantes pour les oiseaux. Les relâchés peuvent, eux aussi, être une source importante de stress, car il arrive que le troupeau d'oies se scinde en groupes de plus petite taille qui se dispersent dans des directions opposées. Ce phénomène est plus fréquemment observé lors de petites captures (quelques familles à la fois). Ceci pourrait avoir des effets négatifs sur l'intégrité des familles d'oies capturées. Seul Williams *et al.* (1993) ont étudié l'effet possible des captures et de la manipulation des oiseaux. Ils ont d'ailleurs observé une réduction du nombre de jeunes par famille suite à la capture.

Le marqueur peut aussi être une source de problème pour l'animal. Plusieurs auteurs ont étudié les effets des radio-émetteurs sur la sauvagine. Cependant, ils arrivent souvent à des conclusions divergentes. De plus, ces chercheurs utilisent les harnais ou les implants pour attacher les émetteurs sur les oiseaux. Chez les oies et les canards, les harnais peuvent affecter des activités telles que l'alimentation, le repos, les déplacements et les activités de confort (Pietz *et al.* 1993, Greenwood et Sargeant 1973, Gilmer *et al.* 1974, Perry 1981). Ces chercheurs rapportent aussi que les oiseaux passaient beaucoup de temps à tirer sur le radio-émetteur. En ce qui a trait aux effets des harnais sur la condition corporelle, Perry (1981) et Greenwood et Sargeant (1973) ont remarqué qu'ils peuvent provoquer l'abrasion des plumes, l'irritation de la peau sous l'émetteur ainsi que la perte de poids chez les canards. De plus, la résistance causée par les harnais montés sur le dos des oiseaux peut réduire la performance de vol des oies (Obrecht *et al.* 1988) et des pigeons (Gessaman et Nagy 1988). À l'opposé, Sedinger *et al.* (1990) n'ont trouvé aucune perte de poids significative mais seulement un effet minimal sur la dépense d'énergie des bernaches cravant (*Branta bernicla*) équipées de radio-émetteur attachés à l'aide d'un harnais.

D'autres recherches ont étudié les effets des colliers conventionnels sans radio. Ankney (1975) affirme que chez la Petite Oie des neiges, les colliers conventionnels provoquent une diminution de temps alloué à l'alimentation, pouvant aller jusqu'à la famine. Cependant, Chabreck (1975) n'a trouvé aucun changement comportemental provoqué par des colliers en Plexiglas. Castelli et Trost (1966) concluent cependant que la survie des bernaches du Canada (*Branta canadensis*) équipées de colliers conventionnels était plus faible que chez celles ne portant que des bagues tarsales. Toutefois, Menu *et al.* (2000) ont démontré que les colliers conventionnels n'avaient aucun effet négatif sur la survie de la Grande Oie des neiges. Craven (1979) affirme aussi que les colliers ne réduisent pas la survie des bernaches du Canada, mais croit qu'il existe une sélection positive faite par les chasseurs pour les oies munies de colliers. Pour sa part, Lensink (1968) a démontré que les colliers retardent significativement la reproduction chez la bernache cravant. À l'opposé, Chabreck (1975) ne rapporte aucune différence significative au niveau de la reproduction des Oies des neiges munies de colliers. Récemment, Schmutz et Morse (2000) ont trouvé une diminution de la survie ainsi qu'une réduction de la taille de ponte chez les Oies empereur (*Chen canagica*) munies de colliers émetteurs comparativement à celles munies de bagues tarsales.

Intégré à une étude plus large sur la migration de la Grande Oie des neiges (*Chen caerulescens atlantica*) utilisant des colliers munis de radio-émetteur, le premier chapitre de cette étude vise à déterminer d'une part si les techniques de marquage utilisées ont des effets négatifs sur le maintien des couples, le succès reproducteur et le comportement de la Grande Oie des neiges et, d'autre part, si les captures massives et les relâchés désordonnés affectent le maintien des couples.

Les taux élevés de séparation tels qu'observés en 1995 (Giroux, données non publiées) entraînent par le fait même la formation de nouveaux couples. De plus, une libéralisation de la réglementation de la chasse ayant pour but de stabiliser la croissance de la population de Grande Oie des neiges a récemment été proposée (Giroux *et al.* 1998). Cette nouvelle réglementation comprend une chasse printanière qui a été instaurée au Québec en 1999. La grande vulnérabilité des jeunes face aux chasseurs, généralement observée l'automne, disparaît au printemps. Par conséquent, les chasseurs récoltent une plus grande proportion d'adultes (Giroux, données non publiées). Ceci provoquerait davantage de bris de couples, et ce, tout juste avant la saison de reproduction.

Les principales conséquences potentielles des séparations et des divorces comprennent la perte du statut de nicheur et un succès de reproduction plus faible. En effet, la monogamie semble aussi avoir des avantages chez les Ansérinés. Ainsi Owen *et al.* (1988) ont observé que les bernaches nonnettes séparées de leur partenaire original et rappariées avec un nouveau ont un succès reproducteur significativement plus faible que celles qui restent unies avec leur partenaire original. Ce phénomène causerait donc une forte sélection contre le divorce (Owen *et al.* 1988). De plus, Forslund et Larsson (1992) expliquent qu'il existe une corrélation positive entre l'âge et le succès reproducteur. Généralement, les individus atteignent leur plus haut taux de succès vers l'âge de 4 à 5 ans. Black et Owen (1995) ont aussi trouvé que le recrutement d'oisons augmente durant les premières années suivant la formation d'un couple, et ce, jusque vers l'âge de 7 à 9 ans chez la bernache nonnette et vers l'âge de 5 à 6 ans pour l'Oie des neiges (Rockwell *et al.* 1993). En fait, Black et Owen (1995) rapportent qu'entre 2 à 6 ans, le recrutement de jeunes augmente de 71 % pour les mâles et de 83% pour les femelles. L'âge, l'expérience ainsi qu'une meilleure coordination entre les deux partenaires lors de la nidification sont donc des facteurs qui contribuent à augmenter le succès reproducteur. Tout ceci pourrait expliquer ce qui pousse les oies à garder leurs partenaires durant plusieurs années. Une autre conséquence potentielle reliée aux séparations et aux divorces est la chute au niveau de la hiérarchie sociale. Raveling (1970) et Scott (1980) ont démontré que chez les oies et les cygnes, la famille est l'unité sociale dominante par rapport au couple et que les couples sont plus dominants que les individus seuls.

Il est généralement établi que la formation des couples survient principalement durant l'hiver (Cooke *et al.* 1975). Toutefois, Owen et al. (1988) ont observé que le rappariement pouvait survenir à n'importe quel moment de l'année. Si les femelles veuves ne peuvent se rapparier avant la saison de reproduction ou que leur succès reproducteur est diminué à cause d'un rappariement avec un nouveau partenaire, la chasse printanière aura donc des effets indirects sur la dynamique de la population de Grande Oie des neiges. De plus, plusieurs études concluent que les paramètres de reproduction des couples unis depuis plusieurs saisons sont supérieurs à ceux des couples nouvellement formés (Black et Owen 1988, Black et Owen 1995, Coulson 1966, Forslund et Larsson 1991, Ollasson et Dunnet 1978). D'autres recherches avancent que les couples d'oies prennent de l'expérience à chaque saison de reproduction et développent une meilleure cohésion ainsi qu'une meilleure coordination (Forslund et Larsson 1992). Le succès de reproduction de ces oiseaux augmenterait alors d'une année à l'autre.

Les objectifs du deuxième chapitre sont de comparer la chronologie de migration, la date d'initiation des nids, la taille de ponte, ainsi que le succès de nidification des femelles munies de radio-émetteur lorsqu'elles sont en couple avec leur mâle original comparativement à celles qui sont pairées avec un nouveau partenaire. Dans ce chapitre, nous chercherons aussi à déterminer la chronologie de rappariement des femelles séparées de leur partenaire original.

CHAPITRE I

# EFFECTS OF COLLAR-ATTACHED TRANSMITTERS ON PAIR BOND, BREEDING SUCCESS AND BEHAVIOR OF GREATER SNOW GEESE.

## 1.1 ABSTRACT

Radio telemetry has played an important role in waterfowl studies to determine space and habitat use, survival and harvest rates as well as migration chronology. Several studies using harness attachment or implants have reached divergent conclusions about potential negative effects of radio transmitters on waterfowl behavior and condition. Our objective was to determine wether radio neck collars affect pair bond, breeding success and behavior of greater snow geese (*Chen caerulescens atlantica*). A total of 230 females were fitted with radio neck collars during the 1995-1998 molting period on Bylot Island, Nunavut, and data were subsequently obtained for 159 birds. Radios were fixed on plastic neck collars with a 15-cm downward antenna for a total mass of 59±9g representing 2.5±0.02% of the female body mass. Over the years (1995 to 1998), 36% (95% CI = 27-45) of the females were separated from their original male after 10 months resulting in an estimated divorce rate of 25% (95% CI = 12-37) when accounting for male mortality rate. In comparison, females with conventional neck collars (without radio) showed a separation rate of 18% (95% CI = 11-25) and a divorce rate of 4% (95% CI = 0-16). Breeding propensity, nest initiation date, clutch size and nesting success of radio marked birds were also negatively affected. Behavioral modifications associated with radio collars were most pronounced in the first fall. Females marked with radio collars spent more time manipulating their collar, doubled their time resting and tended to spend less time foraging than conventional marked females. Behavioral modifications decreased with time, but radios apparently affected long-term reproduction. We recommend to minimize the mass of radio neck collar to ≤ 2.5% of the bird body mass and to reduce antenna length. This implies a trade-off between the effect on birds and the performance of the radio in terms of longevity (battery mass) and range (antenna length).

## 1.2 INTRODUCTION

In recent decades, radio telemetry has played a vital role in many studies of waterfowl ecology. This technique has been used to determine space and habitat use (Hughes *et al.* 1994, Giroux and Patterson 1995, Petrie and Rogers 1997), survival and harvest rates (Ball *et al.* 1975, Eberhardt *et al.* 1989, Schultz *et al.* 1988), migration chronology (Reed *et al.* 1989, Petrie and Rogers 1997) and migration route (Blouin *et al.* 1999) Researchers often assume that capture, handling and marking with radio transmitters do not significantly affect the birds. However, if capture and/or radios have negative effects on marked individuals, the results of these studies might be biased.

Several authors have examined the effects of radio transmitters on waterfowl, but their conclusions were often divergent. Most of these studies used harness or implants as attachment methods. Harnesses can negatively affect activities such as feeding, resting, swimming and comfort movements of geese and ducks (Pietz *et al.* 1993, Greenwood and Sargeant 1973, Gilmer *et al.* 1974, Perry 1981). Gilmer *et al.* (1974) reported that mallards (*Anas platyrhynchos*) and wood ducks (*Aix sponsa*) spent a great deal of time pulling on transmitters. Harnesses can induce feather wear, thickening of the skin under the transmitter and weight loss in ducks (Perry 1981, Greenwood and Sargeant 1973). Moreover, aerodynamic drag of back-mounted radio transmitters can reduce flying performance of geese (Obrecht *et al.* 1988). In contrast, Sedinger *et al.* (1990) found no significant mass loss and minimal effect on energy expenditure in flightless captive brant (*Branta bernicla*) wearing back-mounted radio transmitters. However, their results did not take into account the influence of transmitters on the cost of locomotion because they confined their birds in small cages during metabolism measurements. Although Anserini are generally faithful to their mate and paired for life, Ward and Flint (1995) reported that 90% of the brant marked with harness-attached transmitters were seen without their mate 2-3 months after marking. Harnesses have also been found to interfere with established pair bonds in mallards (Pietz *et al.* 1993, Rotella *et al.* 1993).

Alternative attachment techniques for radio transmitters that would minimize negative effects are therefore required. Implants are used in ducks (Korschen 1984), but are not a good option for geese either with external or internal antenna. Geese may pull on the external antenna with their strong bill, which could cause injuries. Internal antenna do not provide sufficient range which makes difficult tracking of their long-distance movements. Blouin *et al.* (1999) suggested avoiding harness for greater snow geese and recommended fixing radio transmitters on neck collars.

The effects of neck collars even without radio transmitters is also controversial in geese. Ankney (1975) and Raveling (1976) have reported that aluminum neck collars (MacInnes *et al.* 1969) contribute to starvation in lesser snow geese (*Chen caerulescens caerulescens*) while Chabreck (1975) found no changes in behavioral patterns with Plexiglas neck collars. Ely (1990) observed that neck banded greater white-fronted geese (*Anser albifrons frontalis*) spent more time in comfort activity than control geese. Nevertheless, he concluded that neck collars probably did not negatively affect geese because no other activity was affected. Craven (1979) and Chabreck (1975) did not observe any physical impairments such as feather wear or weight loss in neck-banded geese. Some investigators, however, reported that neck collars contribute to starvation (Ankney 1975) and mortality because of neck collar icing (Zicus *et al.* 1983). Castelli and Trost (1996) also concluded that survival of neck-banded Canada geese (*Branta canadensis*) was lower compared to those marked only with leg bands. However, Menu *et al.* (2000) found no effect of neck collars on survival of greater snow geese, which could justify the use of collar to fix radio transmitter. Craven (1979) also concluded that neck collars did not reduce Canada goose survival but believed that hunter selection of neck banded geese may exist. Menu *et al.* (2000) and MacInnes and Dunn (1988) nonetheless found evidence that neck collars could affect other demographic traits such as breeding propensity and emigration. Lensink (1968) also showed that neck collars significantly delayed reproduction in black brant whereas Chabreck (1975) found no adverse effect on reproduction of lesser snow geese. Finally, Schmutz and Morse (2000), the only ones that evaluated the effect of radio collars on breeding performance of geese, found a clutch size reduction for females emperor geese (*Chen canagica*) marked with neck collars and radio collars compared to females with tarsal bands. Furthermore, they found that survival of females marked with tarsal-bands was higher than those marked with collars (with or without radios).

Besides markers, captures may also have adverse effects on birds. The widespread technique to catch geese for marking consist to encircle them during their molt (Owen 1980). Mass captures (300-500 birds) could be a stressful event because of the time the geese spent in the enclosure (3-5 hours). Moreover, scattering of individuals which result in separation of flocks into small groups may occur when the birds are released especially when only a few families are caught (Giroux, pers.obs.). The effects of capture and handling associated with this type of banding operations have rarely been evaluated. Williams *et al.* (1993) observed brood size reduction between pre and post banding operations and Menu *et al.* (submitted) concluded that mass banding drives have no effect on adults and only a slight negative effect on survival of juveniles.

As part of a larger study on the migratory behavior of greater snow geese using radio transmitters mounted on neck collars, we sought to determine whether this marking technique had a negative effect on pair bond, breeding success and behavior of greater snow geese. As birds were captured in family groups, we also examined whether behavior of the family upon release was a good predictor of the maintenance of the pair bond. Finally, some of the radio marked geese were recaptured a few days later during mass captures which allowed us to determine if this method of capture further affected pair bonds.

## 1.3 STUDY AREA AND METHODS

### 1.3.1 Capture & marking

We captured greater snow geese on Bylot Island (Nunavut) each August from 1995 to 1998. A total of 230 adult females were fitted with a radio transmitter (20 in 1995, 60 in 1996, 71 in 1997 and 79 in 1998). In 1997 and 1998, we also replaced the radios of 9 and 10 females, respectively, that had been marked in previous years. Starting in 1996, males associated with the radio tagged females were also marked with conventional plastic neck collars. This facilitated determination of pairing status during the initial capture, recaptures or resightings.

Captures occurred after nonbreeders and failed-breeders had regained flight capabilities. Therefore, all molting adults captured were breeders and were at least two years old because snow geese do not breed as yearling (Cooke *et al.* 1995). Geese were captured by driving groups of 1 to 4 families (3-20 birds) as described by Owen (1980). At this time, juveniles were 25-35 days old. Each capture lasted 15-60 minutes depending on the number of birds. The quality of the release was scored as grouped if all birds walked together or ungrouped if one or more birds immediately splitted from the rest of the group. Families were captured about 5 days before mass captures involving 300-600 birds each, were conducted in the same area as part of the annual banding operations on Bylot Island (Menu *et al.* 2000). Therefore, some of the radio marked geese were recaptured a few days later during mass captures. During this banding operation, 400-500 females were marked each year with conventional yellow plastic neck collars (Menu *et al.* 2000) and served as controls for comparisons to evaluate the effect of the radio collars. All captured birds (young and adults) were also banded with standard USFWS metal bands.

Radios were fixed on green plastic neck collars measuring 5.5-cm high and engraved with 2-alphanumeric codes. Together, the radio and the collar weighted 59±9 g (range: 46-72 g) and represented 2.5±0.02% (range 1.8-3.4%) of female body mass. The radios had a 15-cm long antenna pointing downwards when the bird was standing. In 1997 and 1998, a 3-cm long compressing spring was added to support the antenna at its emergence from the transmitter. The longevity of the radios was about 16 - 18 months with a range of 1 - 2 km on the ground and 4 - 5 km in the air.

Yellow plastic neck collars of males associated with radio marked females, and of females marked during the mass banding operations were 5.5-cm high engraved with 4-alphanumeric codes. Those collars weighted 22 g and represented less than 1% of goose body mass. Both the radio and conventional collars had folded rims which help the collar to slide along the neck whitout brushing up the feathers.

### 1.3.2 Social status

Social status of marked birds was repeatedly determined when they were located by radio tracking and observed during the fall and spring staging periods along the St. Lawrence River in Quebec, or during the subsequent breeding seasons on Bylot Island. Five to 7 persons tracked the geese daily throughout the staging grounds while 2 persons tracked the birds on the goose colonies during the summer. We determined status changes within and between seasons as well as between years. The status in year $i$+1 after marking was based on observations conducted both during the spring staging period in Quebec (end of March to end of May) and the breeding period on Bylot Island (early June to mid-August). We considered that we could pool spring and summer status observations because there were very few separations that occurred between spring and summer periods (3%, n = 33). The median observation date corresponded to mid-June. Therefore, we considered that the status in year $i$+1 and $i$+2 was established 10 and 22 months, respectively, after banding. A radio marked female could be paired with its original mate (male with a conventional neck collar and/or a leg band), alone or paired with a new partner (uncollared and unbanded). Females fitted with conventional collars were also observed by the same crew who established if they were paired with their original mate (male with a leg band), alone or paired with a new partner (unbanded). We assumed that the original mate of a neck collared female should be wearing a leg band because both members of a pair werre caught during a capture and all individuals of a catch were banded. We also assumed that in the event of a change of mate, it is unlikely that her new mate would also be banded because of the low frequency of banded birds in the population. We considered that at least 2 observations during the same season were required to establish that a neck collared female was alone or with a new male. Because of possible temporary liaisons (Choudhury and Black 1993), it was impossible to ascertain that the new partner of a given goose was always the same individual. During the following season, re-observations of females separated from their new mate confirmed temporary liaisons, but it was impossible to be sure that their new mates were the same or if another separation or divorce have occurred. On the other hand, only one observation of a radio tagged female associated with its original marked male was sufficient to establish that no status change had occurred.

### 1.3.3 Breeding parameters

Radio marked geese were monitored during the years following their initial marking to determine their reproductive output. Breeding propensity (the proportion of females located at Bylot Island that attempted to nest), nest initiation date (date that first egg was laid), clutch size and nesting success (proportion of nests where at least one egg hatched successfully) of the radio marked birds were recorded in 1997 and 1998. Most nests were found during laying or early incubation. Nests of unmarked geese monitored within the colony served as controls (Lepage *et al.* 2000). Finally, brood success (proportion of females with at least one young) was established during the fall and subsequent spring on the staging grounds along the St. Lawrence River in Quebec.

### 1.3.4 Activity budget

Activity budgets were determined during spring and fall staging in 1998 on females marked with radio collars, conventional neck-collars and without collars (control). Focal observations (Altman 1974) were conducted and data recorded in continuous mode with a hand-held computer. Seven activities were recorded during sampling periods varying between 15 and 30 min: feeding (head below horizontal, including drinking, grazing, grubbing or searching for food), manipulating the collar (preening feathers near the collar, pecking at the radio or at the collar or pulling the antenna), comfort (all comfort activities excluding those associated with the collar or the radio), resting (sleeping or loafing with closed eyes or head tucked under feathers), alert (head up standing still on land or water), locomotion (walking head up, swimming or flying) and social interactions (pecking or chasing other birds or being pecked at or chased).

Radio marked birds were randomly chosen among those present at a site. Once an observation bout was completed, the nearest conventional neck-collared female was selected. Finally, to select a control female without collar, we randomly chose an unmarked family. Based on size (Cooke *et al.* 1995) and behavioral differences between adult males and females, we then determined which bird was the female. We tried to have the same number of observation bouts for the three groups of birds, for both daily periods (morning and afternoon) as well as for the various habitats (hayfields, cornfields, marshes and open water).

To avoid pseudo-replication, we first abstained to do repeated observations on the same females when possible. However, because different observers located the same marked birds at different sites, some birds were observed more than once. For birds with a radio collar, a maximum of 4 bouts were recorded on any given female and 2 for females with neck collar. We used the mean of repeated observations to insure that each female contributed a single value to the analysis. For control females, it is unlikely that the same birds were chosen more than once because of the large number of birds in the observed flocks (1000 – 40 000).

### 1.3.5 Data analysis

The probability of observing a marked female with its original mate at time $i + 1$ ($\theta$, $\theta$ = 1 - separation rate) can be viewed as the probability of two independent events: the probability for the mate to survive from $i$ to $i + 1$ ($S$) and the probability that the two partners are still together ($\tau$, $\tau$ = 1- divorce rate) given that the male survives, thus:

$$\tau = \frac{\theta}{S}.$$

If we know the survival rate of the mate ($S$), it is possible to calculate the divorce rate. Annual survival has been precisely estimated for adult female greater snow geese, but not for male (Gauthier *et al.* in press). Usually, there is few difference between male and female survival rate in adult snow geese (Francis and Cooke 1992). Although survival rate is not constant throughout the year, annual variations are slight (Gauthier *et al.* in press). Consequently, we used survival rate determined for female (83%) by Gauthier *et al.* (in press) and assumed that this rate was constant during a year. We calculated survival for 10 and 22 months periods with the formulas:

$$S_{10months} = S_{annual}^{(10/12)} = 0.83^{(10/12)} = 0.856$$
$$S_{22months} = S_{annual}^{(22/12)} = 0.83^{(22/12)} = 0.711\ .$$

For separation rate, nesting success and proportion of females alive, we assumed a normal distribution and calculated standard error (SE) and 95%CI using these formulas:

$$\mathrm{SE} = \sqrt{(p * q)/n}$$

$$95\%\mathrm{CI} = \mathrm{SE} * (\pm 1{,}96)\ .$$

Standard error (SE) associated to annual survival has been established at 0.048 (Gauthier *et al.* submitted). Standard error for a 10- and 22-month period can be calculated by the delta method of Seber (1982) as folows :

$$\mathrm{SE}_{10months} = \sqrt{\left[(10/12)S^{((10/12)-1)}\right]^2 * \mathrm{SE}^2} = 0.041$$
$$\mathrm{SE}_{22months} = \sqrt{\left[(22/12)S^{((22/12)-1)}\right]^2 * \mathrm{SE}^2} = 0.075\ .$$

When we divide (1- separation rate) by survival rate, we have an error associated with the determination of (1- separation rate) and an error associated with survival. We have to take into account both errors to calculate the error on the estimated divorce rate:

$$\mathrm{SE}_\tau = \sqrt{\left[\left(-\frac{\theta}{S^2}\right)^2 * \mathrm{SE}_S^2\right] + \left[\left(\frac{1}{S}\right)^2 * \mathrm{SE}_\theta^2\right]}\ .$$

We used Pearson chi-square tests to compare the proportion of females separated from their original mate between radio marked females and those fitted with conventional collars, 10 and 22 months after banding. We considered that conclusions from tests on separation could be applied to divorce rates since the same survival rate was applied to all separation rates to obtain divorce rates. We used a t-test to compare the percentage of the female body mass represented by the radio collar between females paired with their original male and those separated form their original mate 10 months after marking. We also used chi-square tests to compare nest success and brood success between females with radio transmitters and those with conventional neck collars. We conducted the same tests to compare the proportion of females separated from their original mate 10 months after marking between 1) birds recaptured and those not recaptured during mass banding operations and 2) between birds with grouped and ungrouped releases. Finally, we used a median test, a Wilcoxon rank sum test and a chi-square test to respectively compare nest initiation dates, clutch size and apparent nesting success between radio marked females and unmarked females.

For each observation bout, we used time spent in the various activities to calculate the percentage of time allocated to each activity and an angular transformation was applied to those percentages (Sokal and Rohlf 1995: 419). We used a multivariate analysis of variance (MANOVA) with collar types (radio, conventional, none) and status (paired, unpaired) as factors for each season. Tukey's tests were conducted to determine which activities differed among collar types.

## 1.4 RESULTS

### 1.4.1 Goose pairing

The relative mass of the radio collar did not differ ($t = 0.274$; $df = 110$; $p = 0.785$) between females paired with their original male (2.37±0.05%, $n = 72$) and those separated from their original male (2.34±0.07%, $n = 40$).

No difference in the probability of separation occurred among years for radio marked geese ($\chi^2 = 0.92$; $df = 3$; $p = 0.821$) as well as for geese marked with conventional collars ($\chi^2 = 0.92$; $df = 1$; $p = 0.339$). We therefore pooled the data of the different cohorts (Table 1.1). Probability of separation for radio marked females was twice as high as for females with conventional collars, either 10 months ($\chi^2 = 9.47$; $df = 1$; $p = 0.002$) or 22 months ($\chi^2 = 8.81$; $df = 1$; $p = 0.003$) after marking. After correcting for male survival, we obtained similar divorce rate of 25% and 30% after 10 and 22 months respectively, for females with radios. Very few divorces occurred for females with conventional collars, our estimates varying from 4% to 0%, 10 and 22 months after marking.

Among the separated females marked with radio collars, 45% and 53% were paired with a new partner 10 and 22 months after marking, respectively (Table 1.2: $\chi^2 = 0.30$; $df = 1$; $p = 0.583$). The others were still alone. Fifty percent (6/12) of the radio marked females observed with a new mate during the first spring were observed alone the following fall or the next spring. Among females marked with conventional collars, 48% and 57% of the females that had lost their original mate were paired with a new mate 10 and 22 months after marking ($\chi^2 = 0.41$; $df = 1$; $p = 0.524$). The proportion of females alone or paired with a new partner was not significantly different between radio collars and conventional collars 10 ($\chi^2 = 0.04$; $df = 1$; $p = 0.845$) and 22 months ($\chi^2 = 0.08$; $df = 1$; $p = 0.782$) after marking.

**Table 1.1** Percentage of female greater snow geese fitted with radio collars and conventional collars, separated and divorced from their original mate 10 and 22 months after banding.

| Months | | Radio | | | | | Conventional | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| After | | | Separated | | Divorced* | | | Separated | | Divorced* | |
| Marking | Cohort | n | % | 95% CI | % | 95% CI | n | % | 95% CI | % | 95% CI |
| 10 | **1995** | 12 | 33 | 7-60 | 22 | 0-54 | - | - | - | - | - |
| | **1996** | 42 | 40 | 26-55 | 30 | 12-49 | - | - | - | - | - |
| | **1997** | 37 | 35 | 20-51 | 24 | 5-44 | 40 | 23 | 10-35 | 9 | 0-27 |
| | **1998** | 21 | 29 | 9-48 | 17 | 0-40 | 78 | 15 | 7-23 | 1 | 0-14 |
| | **Total** | 112 | 36 | 27-45 | 25 | 12-37 | 118 | 18 | 11-25 | 4 | 0-16 |
| 22 | **1995** | 6 | 83 | 54-100 | 77 | 34-100 | - | - | - | - | - |
| | **1996** | 21 | 43 | 22-64 | 20 | 0-54 | 47 | 21 | 10-33 | 0 | 0-18 |
| | **1997** | 11 | 45 | 16-75 | 23 | 0-68 | 75 | 27 | 17-37 | 0 | 0-22 |
| | **Total** | 38 | 50 | 34-66 | 30 | 3-56 | 122 | 25 | 17-32 | 0 | 0-18 |

* Taking into account male survival

**Table 1.2** Percentage of the separated females fitted with radio collars and conventional collars with a new partner 10 and 22 months after banding.

| | | | With a new partner | |
|---|---|---|---|---|
| **Months after marking** | **Collars** | **n** | **%** | **95% CI** |
| **10** | **Radio** | 40 | 45 | 30-60 |
| | **Conventional** | 21 | 48 | 26-67 |
| **22** | **Radio** | 19 | 53 | 30-75 |
| | **Conventional** | 30 | 57 | 39-74 |

### 1.4.2 Effect of release and recapture

Radio marked geese had a similar separation rate regardless of the quality of the release (grouped vs ungrouped) ($\chi^2 = 0.93$; df = 1; p = 0.334). We observed 36% (95% CI = 26-45%, n = 88) of separation among geese that remained as a group on release and 25% (95% CI = 6-44%, n = 20) for those that scattered when released. There were no difference in the proportion of females separated from their original mate for birds recaptured during mass banding (33% , 95% CI =13-54%, n = 21) compared to birds not recaptured (31%, 95% CI=21-40%, n = 91, $\chi^2 = 0.05$; df = 1; p = 0.819).

### 1.4.3 Reproductive parameters

Breeding propensity of radio marked birds was 59% (20/34) in 1997 and 57% (19/34) in 1998. This proportion was not available for conventional neck-collared or unmarked geese. In 1998, females marked 10 or 22 months before had similar median nest initiation dates, June 11$^{th}$ (n = 18) and June 10$^{th}$ (n = 10) respectively (z = -0.50; p = 0.618). Clutch size was also similar 10 (2.83±0.19, n = 18) and 22 months (3.20±0.20, n = 10) after marking (z =

1.24; p = 0.215). Finally, nesting success did not differ significantly between females that had a radio for 10 (53%, n = 19, CI 30-75) and 22 months (60%, n = 10, CI 30-90; $\chi^2 = 0.14$; df = 1; p = 0.705).

Geese fitted with radio 10 and 22 months earlier initiated their nests significantly later than the rest of the population both in 1997 (z = 3.49; p < 0.001) and 1998 (z = 6.45; p < 0.001) (Table 1.3). In addition, clutch sizes of radio marked geese laid about 1.5 eggs fewer than for the control population in 1997 (z = -5.04; p < 0.001) and 1998 (z = -5.75; p < 0.001). Nesting success was lower for radio marked geese than for the overall population in both years (1997: $\chi^2 = 13.29$; df = 1; p < 0.001, 1998: $\chi^2 = 8.85$; df = 1; p = 0.003).

**Table 1.3** Nest initiation date (median), clutch size (mean ± SE) and nesting success (mean, 95% CI) of females marked with radio collars and unmarked control geese, 1997-1998.

| Variables | Year | n | Radio marked | n | Unmarked |
|---|---|---|---|---|---|
| **Nest initiation date** | **1997** | 20 | June 14 | 326 | June 10 |
| | **1998** | 28 | June 10 | 339 | June 7 |
| **Clutch size** | **1997** | 20 | 2.75±0.27 | 289 | 4.27±0.10 |
| | **1998** | 28 | 2.96±0.14 | 299 | 4.10±0.10 |
| **Nesting success** | **1997** | 20 | 50 (28-72) | 317 | 83 (79-87) |
| | **1998** | 29 | 55 (37-73) | 333 | 79 (75-84) |

* in 1998, 18 birds 10 months and 10 birds 22 months

**Table 1.4** Percentage of females fitted with radio collars and with conventional neck collars with at least one young, during their second fall and spring following banding in 1997 and 1998.

| Collars | Fall | | Spring | |
|---|---|---|---|---|
| | n | % (95% CI) | n | % (95% CI) |
| **Radio** | 20 | 15 (0-31) | 15 | 7 (0-19) |
| **Conventional** | 49 | 31 (18-44) | 47 | 19 (8-30) |

During the second fall and spring following marking, the proportion of females accompanied by at least 1 young was 50% lower in females marked with radio collars compared to those marked with conventional neck collars, but differences were not significant (second fall: $\chi^2 = 1.80$; df = 1; p = 0.180; second spring: $\chi^2 = 1.31$; df = 1; p = 0.253; Table 1.4).

### 1.4.4 Activity budget

We completed 32 observation bouts on radio marked birds, 27 on geese marked with conventional collars and 57 on unmarked females in spring and fall 1998 for a total of 57 hours of focal observation. In the first fall, about 2 months after marking, activity budgets differed among paired females fitted with radios, conventional neck collars or no collar (Wilks' lambda = 0.266; F = 3.22; df = 14 and 48; p = 0.001; Fig. 1). A similar difference was observed for lone females marked with radio or conventional collars (Wilks' lambda = 0.037; F = 11.30 ; Num df = 7 and 3; p = 0.036). Our sampling procedure precluded the observation of unmarked lone females. Paired females marked with radio collars spent more time manipulating their collar than conventional collared and unmarked females. They also doubled their time resting. Although it was not significantly different, probably because of the small sample size, the radio marked females either alone (F = 2.56; df = 1 and 9; p =

0.144) or paired ($F = 2.77$; df = 2 and 30; $p = 0.079$), tended to spend less time in foraging activities. There was no difference in feeding activities between females with conventional collars and those of the control group. Lone females spent much more time in comfort activities than paired females ($F = 11.32$; df = 1 and 9; $p = 0.008$).

The effect of the radio neck collars on behavior decreased with time. In the spring following marking, there was still a significant difference for paired females among radio marked geese, conventional marked geese and control females (Wilks' lambda = 0.394; $F = 3.89$; df = 14 and 92; $p = 0.001$; Fig 2). However, the only significant difference occurred with the collar-related activity for females with conventional neck collars although the sample size was small. This slight difference did not have any repercussion on other important activities like foraging, resting or alert. No difference was observed in spring for lone females that were either fitted with a radio transmitter or a conventional neck collars (Wilks' lambda = 0.413; $F = 1.83$; df = 7 and 9; $p = 0.197$).

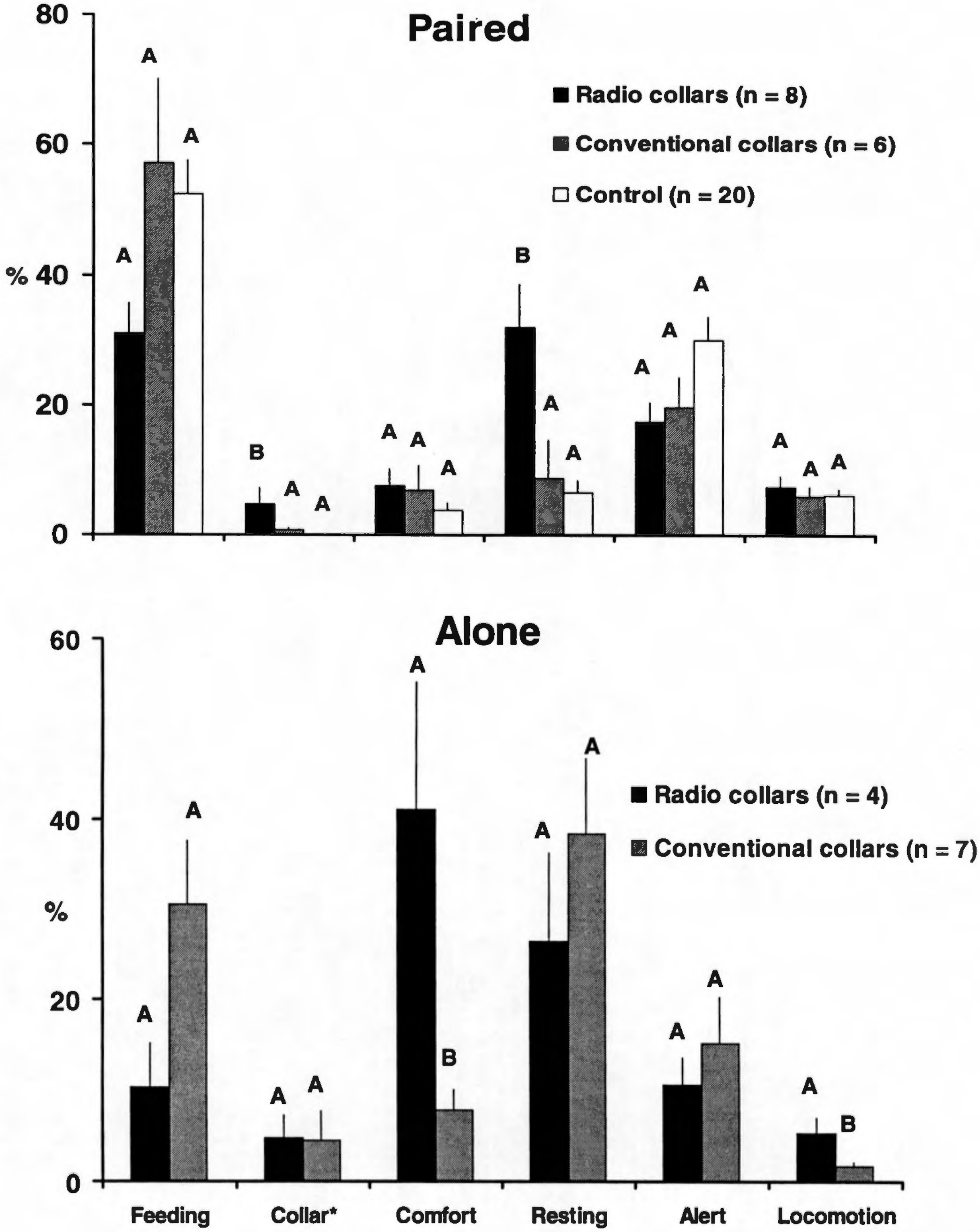


Figure 1.1 Activity budget (%, SE) of paired and lone females during fall 1998. Bars with the same letter do not differ significantly between groups within the same activity. Collar* = collar manipulation.

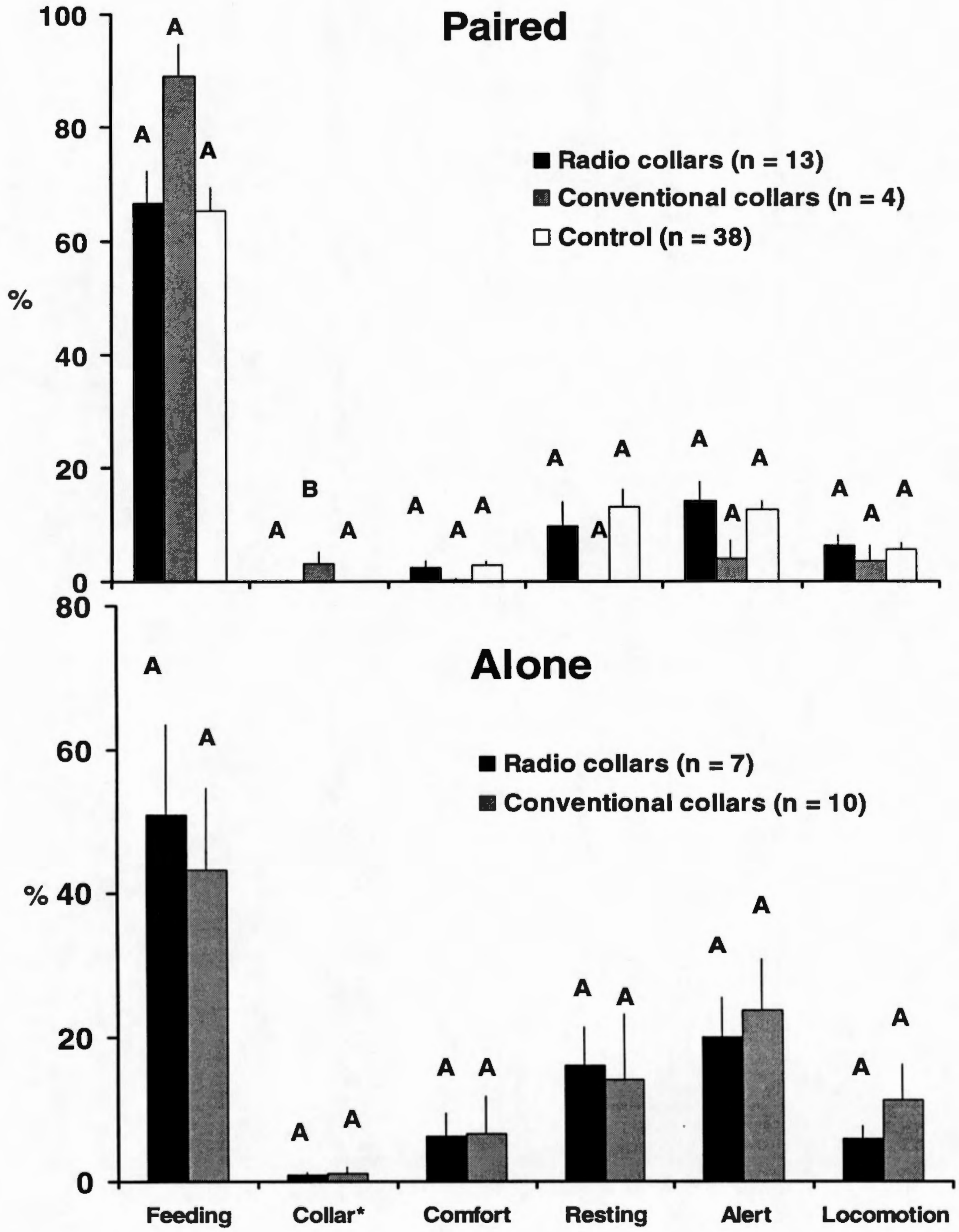


Figure 1.2 Activity budget (%, SE ) of paired and lone females during spring 1998. Bars with the same letter do not differ significantly between groups within the same activity. Collar* = collar manipulation.

## 1.5 DISCUSSION

Annual separation rate of pair members in Anserini has been established at 10-20% (Forslund and Larsson 1991, Owen *et al.* 1988, Raveling 1989). Considering that this value is similar to annual mortality rate, this means that divorces are rare. In barnacle geese (*Branta leucopsis*), divorce rate was estimated at only 2% (Owen *et al.* 1988, Forslund and Larsson 1991). This is consistent with our observations on female greater snow geese fitted with conventional neck collars which suggested a divorce rate between 0 - 4 %. This indicates that greater snow geese, like other Anserini, form strong and durable pair bonds and that conventional neck collars do not contribute importantly to divorces. In contrast, we found that radio marked birds had a divorce rate as high as 25% in their first year, which is much higher than reported in the literature and observed for females marked with conventional neck collars. Divorce was most important during the first months following marking because it increased only from 25 to 30% in the second year.

Prevett and MacInnes (1980) suggested that for lesser snow geese, greater density of geese, larger flock size and higher rates of disturbance in fall compared to other seasons can cause frequent temporary splitting of families. However, they reported that most of the time, separated family members regrouped. We did not record any temporary separations of pairs between fall and spring. We therefore reject the hypothesis of accidents to explain the greater divorce rate of radio marked females.

Cooch (1953) and Prevett and MacInnes (1980) indicated that marking operations could have negative effects on pair bonds. Prevett and MacInnes (1980) found that 11-22% of paired adults had not reunited a week after banding. Our results do not support their contention because mass captures and ungrouped releases had no effect on pair bond 10-22 months later. Pairs that split during an ungrouped release either may reunify and those released together may eventually divorce which resulted in a similar percentage of separation. Hence, we also reject the hypothesis that high separation rates of radio marked geese was a consequence of capture and release.

Ely (1990) indicated that neck collars did not negatively affect greater white-fronted geese as no other activities than preening were affected. He suggested that marking devices were more likely to affect the behavior of the geese immediately after capture. Activity budget of females marked with conventional neck collars was weakly or not affected in the months following marking and we found no evidence that foraging activity was reduced, at least for paired females. Ankney (1975) suggested that neck collars could reduce time spent foraging by geese. This difference may be explained by the type of collars used. Ankney (1975) used aluminum collars whereas ours were made of plastic.

During the fall following marking, activity budget of radio marked females was different from neck-collared and unmarked geese. The high amount of time spent manipulating their collars and in comfort activities may have been related to the presence of the radio antenna extending into the plumage. When geese were preening neck feathers at the base of the collar or on the breast, the collar and the antenna seemed to disturb the birds which increased their time in comfort activity. Radio collars may also have induced abnormal behaviors, such as females walking backwards, which may contribute to pair break up (Demers and Giroux pers. obs.). Consequently, we suggest that females which did not habituate to their collar lost their mate rapidly because of changes in their behavior.

Radio marked females paired with their original partner doubled their time resting. This could result from the extra effort needed to carry a radio collar, weighting about 2.5% of the bird body mass. Sedinger *et al.* (1990) found that radio marked captive black brant with backpack-mounted harnesses weighing 35 g (2.3% of the body mass) had an energy budget similar to that of control females without harness. However, this did not take into account the influence of transmitters on the cost associated with flying. For greater snow geese, which must complete a 3000-km migration from the Arctic breeding grounds to the St. Lawrence River staging grounds in Quebec, the additional weight may increase energy expenditure and result in more time resting when they arrive on the staging grounds. This in turn may influence the rest of the activity budget. Although our results show that feeding activities did not differ significantly for females marked with radio transmitters and controls. It nevertheless tended to be much lower compared to control and the lack of significance may be due to small sample size.

In the following spring, the effect of radio transmitters on behavior had disappeared possibly because of habituation after this 9-month period. However, almost all radio marked females had cut their antenna by then. This may have eliminated one of the major irritant of the radio collars, resulting in a similar activity budget for marked and unmarked birds.

Reproduction of radio marked geese was first impaired by an increase in separation rates attributed to divorces. Breeding propensity was also apparently reduced. The radio marked geese were ≥ 3 years old when breeding in the year following their initial marking. We therefore expected a breeding propensity close to 85%, as estimated for adult lesser snow geese at La Perouse Bay (Rockwell *et al.* 1997), but we only obtained 57-59%. Even if our percentage could include birds that attempted to breed and that failed very early, the observed difference is very important and suggested that radio neck collars might have a direct impact on breeding propensity.

The presence of radio neck collars negatively influenced all nesting parameters. This effect even persisted 22 months after marking. Radio marked geese initiated their nest 3 days later than the rest of the population. Even if the control group came from a restricted area of the breeding colony whereas nests of radio marked geese were dispersed in the breeding colony, the observed differences in the timing of nest initiation (3-4 days) is very large considering that 90% of all nests are initiated over an 8-day period (Lepage *et al.* 2000). Therefore, it is unlikely that it can be explained only by a sampling bias. Clutch size of radio marked geese was also smaller than for the rest of the population. Lepage *et al.* (2000) observed a clutch size decline of 0.2 egg/day laying delay. Therefore, a 3-4 days initiation date delay should have induce a clutch size decrease of 0.6-0.8 egg whereas we observed a decrease of 1.5 eggs. It suggested that the radio collars have an additional effect on clutch size. Schmutz and Morse (2000) also observed a decline in clutch size in emperor geese marked with radio neck collars and conventional collars. However, Chabreck (1975) reported no negative effects of neck collars on reproduction in lesser snow geese. Nesting success of the radio marked geese was also lower than in the control group. Furthermore, even if it was not statisticaly different, possibly because of the small sample sizes, there was 50% fewer females with radio collars accompanied by at least 1 young than females marked with conventional neck collars.

Fat accumulation in spring is a major determinant of reproductive success in geese (Ankney and MacInnes 1978, Ryder 1970). In spring, radio marked geese fed at similar rates than neck-collared and unmarked geese and should therefore not have been disadvantaged in accumulating fat reserves. Moreover, there is no evidence that radio marked geese were using sub optimal habitats during their spring staging period in Quebec (Béchet, A. UQAM, pers. comm.). Gessaman and Nagy (1988) and Obrecht *et al.* (1988) reported that radio transmitters mounted on the back of pigeons and snow geese increased aerodynamic drag. Geese marked with radio collars might therefore have to expend extra efforts to fly and to use more of their fat reserves to complete their spring migration (Gauthier *et al.* 1992). Consequently, radio neck collars might delay arrival date on the breeding grounds and have a negative impact on fat reserves remaining on arrival by increasing the energetic cost of migration. This may be especially true in spring because geese are at maximum weight comparer to the rest of the year. At that time of the year, fat reserves represent about 25% of their weight (Gauthier *et al.* 1992) which means that wing loading is maximum. Pennycuick *et al.* (1996) showed that swans have a very important wing loading attributed to fat reserves when they start their migration. Swans are then at the limit of their flying capability. Hence, the additionnal mass attributed to the collar, which represents 2.5% of the bird body mass, may be especially significant because the effect of this additionnal mass may be nonlinear. Over the threshold of flying capability, a small addition of weight may have important effect on energy expenditure. Radio neck collars may have also increased the pre-laying period of geese that required more time to rebuild their energy reserves (Gauthier and Tardif 1991). Therefore, a negative effect of radio collars on fat reserves and on the arrival date on the breeding grounds may be the most likely cause for reduced reproductive output of radio marked geese.

## 1.6 RECOMMENDATIONS

Radio collars induced some divorces of greater snow geese through behavioral modifications and reduced reproductive success. Behavioral modifications seemed to decrease over time, but radio collars affected reproduction up to two years after marking. We nonetheless believe that the use of neck collars to fix radio transmitters is better than harnesses in snow geese. The separation rate observed in our study (36%) is much lower than the 90% recorded by Ward and Flint (1995) in brant. Moreover, harnesses are difficult to adjust on molting geese because they must not be fitted too tightly to account for future expansion of the breast muscles and should not be fitted too loosely as a bird can get its foot entangled (Giroux, pers. obs.). Implanting transmitters, which has been suggested for ducks (Rotella *et al.* 1993), may not be suitable for geese. Using an external antenna on these implants, which is required to provide adequate range, would not be suitable because geese could pull on the antenna and cause injuries. Consequently, radio transmitters fixed on neck collars remain an interesting option for telemetry studies on geese, but need to be improved considering the potential biases. Kenward (1987) and Cochran (1980) recommended that markers should not represent more than 2-3% and 5%, respectively, of the bird body mass. For greater snow geese, we recommend that weight of radio neck collars should be less than 2.5% of the body mass. Secondly, we recommend shortening of the antenna. A compromise between the potential negative effects of the attachment technique on the bird behavior and the performance of the transmitters in terms of longevity (battery weight) and range (antenna length) should be achieved. Researchers should always remain alert about the potential effects of their marking techniques.

## 1.7 LITERATURE CITED

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# CHAPITRE II

# MATE LOSS IN GREATER SNOW GEESE: FATE OF FEMALES AND REPRODUCTIVE OUTPUT

## 2.1 INTRODUCTION

Although 90% of all birds' species are monogamous, long-term pair bonds are relatively rare (Lack 1968, 1974). Perennial monogamy is associated with large body size, high probability of mate survival, lack of renesting opportunities, and extended bi-parental care (Oring and Sayler 1992). In barnacle geese (*Branta leucopsis*), long-term pair bonds lasting for several breeding seasons enhance cohesion and coordination between mates (Forslund and Larsson 1992). Numerous studies have reported that breeding performance of long-lasting pairs were significantly better than those of newly formed pairs (Black and Owen 1988, 1995, Coulson 1966, Forslund and Larsson 1991, Ollasson and Dunnet 1978). For instance, nest initiation date advanced with duration of the pair bond in Gannet (*Sula bassana*) (Nelson 1966) and Great skua (*Catharacta skua*) (Catry *et al.* 1997). Nesting and hatching success as well as the proportion of fledging chicks increased with breeding experience respectively in Gannet (Nelson 1966), Manx Shearwater (*Puffinus puffinus*) (Brooke 1978) and in fulmar (*Fulmarus glacialis*) (Ollasson and Dunnet 1978). Finally, brood success in Great skua was better for older than newly formed couples (Catry *et al.* 1997). However, Cooke *et al.* (1981) found no relationship between mate loss and lower clutch size in lesser snow geese (*Anser caerulescens caerulescens*). They suggested that a smaller clutch size for birds that lost their mate was more likely due to the fact that more first time breeders separated. Hence, it is normal that birds breeding for their second time have a lower reproductive success than older birds.

Many authors have estimated annual separation rate at 10 to 21% in Anserini (Forslund and Larsson 1992, Owen *et al.* 1988, Raveling 1989). Separation can be caused by the death of the mate or by a divorce, but 75% of separations have been attributed to the mortality of the mate in barnacle geese (Forslund and Larsson 1991). Potential consequences of separation include loss of breeding status and temporary lower reproductive success as shown in oystercatcher by Ens *et al* (1993). Separated birds might also have a lower ranking in the dominance hierarchy in a flock because families are dominant over pairs and pairs over unpaired birds in geese and swans (Raveling 1970, Scott 1980).

Owen *et al.* (1988) predicted that separation rate could increase up to 30-40% in populations where hunting pressure is important. Because hunting typically occurs in fall and winter, this should leave enough time for birds to replace a lost partner. Indeed, it is generally believed that pair formation in snow geese occurs on the wintering grounds (Cooke *et al.* 1975), although Owen *et al.* (1988) noted that pair formation could occur at any time of the year. Spring conservation hunt, a measure proposed to control the rapidly expanding population of greater snow geese (Giroux *et al.* 1998), was recently introduced in Quebec. In spring, the greater vulnerability of juveniles to hunting observed in fall has disappeared resulting in an increased proportion of adults in hunter's bags (Giroux, unpublished data). This new hunting regulation might therefore induce more break ups of pairs just prior to the breeding season. If separated females cannot pair with a new mate before the coming breeding season or if their reproductive output is reduced because of their pairing with a new mate, this could be an additional indirect effect of the spring hunt on the greater snow goose population dynamics (Francis 2000).

In this paper, we evaluated the fate of separated females and their subsequent breeding success. We first determined the timing of pairing for radio-marked females that were separated from their original mate. We also compared spring migration chronology, nest initiation date, clutch size and nesting success between females paired with their original mate and those with a new mate.

## 2.2 STUDY AREA AND METHODS

In 1996 and 1997, we marked 60 and 71 females with radio-transmitter fixed on neck collars respectively. The birds were captured on Bylot Island (Nunavut) in August when adults were molting and before the juveniles fledged. Only adults that had attempted to breed were captured because non-breeders or those that failed nesting early had regained flight capabilities and left the island by that time (Menu *et al.* 2000). Geese were captured by driving groups of 1 to 4 families (3-20 birds) using the technique described by Owen (1980). The radios were fixed on green plastic neck collars, resulting in a package weighing 59±9 g (range: 46-72 g) that represented 2.5±0.02 % (range 1.8 - 3.4 %) of female body mass. Males accompanying these females were fitted with conventional yellow plastic neck collar with individual alpha-numeric codes (Menu *et al.* 2000). All birds (young and adults) also received standard USFWS metal leg bands. These markers allowed identification of the female, determination of its status (alone, with the original mate or with a new unmarked one), and determination of the number of accompanying young. Pairing status was determined at capture (or upon release) and during subsequent recaptures or resightings. Intensive observations were conducted during the subsequent fall and spring staging periods along the St. Lawrence River in Quebec or during the following breeding seasons on Bylot Island. See Demers *et al.* (in prep) for more details on tracking and observations.

Females that had retained their original mate 10 months after marking were compared to those with a new mate with respect to departure date from the spring staging area, arrival date on the breeding area, nest-initiation date, breeding propensity (the proportion of the females located at Bylot that attempted to nest), clutch size, apparent nesting success (proportion of nests where at least one egg hatched successfully) and brood success (proportion of families accompanied by at least one young on staging ground during either the second fall and spring). Dates were relative to annual median dates of paired females marked with radio collars for departure date, arrival date and nest-initiation date to take into account annual differences in dates.

Pearson chi-square or Fisher exact tests were used to compare the proportion of breeding attempts, nesting success and brood success of females paired with their original male and those paired with a new male. We used t-tests to compare mean relative departure and arrival dates, mean nest initiation dates and mean clutch sizes between old and newly formed pairs even if some samples were not normally distributed. Finally, due to small sample sizes we calculated the power of those tests. For t-tests we used the power option in JMP and for Pearson chi-square and Fisher exact tests, we used the macro POWERRxC of SAS. In both case, the level of the test was established at 5%. The power represents the probability of getting a significant result when we try to detect a 5% difference between the two groups.

## 2.3 RESULTS

During our study, 31 of the 79 females for which we had a status were separated from their males with which they were captured during their previous molt. In spring, six females had already remated with a new partner and 21 were still alone on the St-Lawrence river staging grounds. Of these 21 females, seven were not detected on the breeding grounds, two were still alone, four were detected for a brief period but not observed indicating that they might still be unpaired, one remated with her original mate and seven remated with a new partner before the onset of the breeding season. Another female accompanied by its original mate in spring nested with a new male while three others for which we failed to establish a status in spring also bred with a new partner. We therefore estimated that 58% (18/31) is a minimun rate of repairing on an annual basis and 41% (9/22) for females that were alone or became separated in spring .

The mean relative departure date from the staging grounds and arrival date on the breeding grounds of females paired with their original mate were not significantly different than from those of females paired with a new partner. No difference was observed in either the proportion of breeding attempts or nest initiation dates between females paired with their original partner or with a new partner (Table 2.1). Clutch sizes of females who had retained their original mate tended to be higher than those paired with a new male, but the difference was not statistically significant. Nesting success did not differ either. Of the eight females that remated at the onset of the breeding season, only three had a successful nests compared to two out of three for females that were already remated in spring (Fisher's exact test P=0.364). In the second fall after marking, females accompagnied by new mates were equally successful in bringing young to the staging area as those with their original mates. By the second spring, however, some of those females with original mates were still accompagnied by young whereas none of those with new mates were. The power of our tests at the 5% level was low (5-18%) reflecting our small sample for females with new partner.

TABLE 2.1 Migration chronology and breeding parameters for radio-marked female greater snow geese paired with their original partner or with a new partner, 1997-1999.

| | Original | | | New | | | p | Power |
|---|---|---|---|---|---|---|---|---|
| | n | Mean | 95% CI | n | Mean | 95% CI | | $\alpha$=0.05 |
| Departure date from staging ground [a] | 41 | -0.76 | -1.62-0.11 | 6 | -1.00 | -3.02-1.02 | 0.843 | 0.05 |
| Arrival date on Bylot Island [a] | 36 | -1.06 | -2.69-0.58 | 6 | -2.33 | -5.97-1.30 | 0.561 | 0.09 |
| % breeding attempt | 30 | 90 | 79-100 | 14 | 79 | 57-100 | 0.304 | 0.18 |
| Nest-initiation date [a] | 25 | -0.56 | -1.52-0.40 | 11 | -0.27 | -1.72-1.18 | 0.748 | 0.06 |
| Clutch size | 26 | 2.92 | 2.52-3.33 | 11 | 2.55 | 1.99-3.10 | 0.311 | 0.17 |
| % nesting success | 27 | 56 | 36-75 | 11 | 45 | 15-75 | 0.572 | 0.09 |
| % brood success in second fall | 14 | 14 | 0-33 | 6 | 17 | 0-47 | 0.891 | 0.05 |
| % brood success in second spring | 10 | 10 | 0-29 | 5 | 0 | 0 | 0.667 | 0.11 |

[a] Dates are relative to annual median dates for radio marked birds with a known status.

## 2.4 DISCUSSION

Demers *et al.* (in prep.) found that radio transmitters attached to neck collars induced divorces through behavioral modifications of females during their first fall. They also found a reduction in breeding success for radio-marked females compared to unmarked birds. In this study, the effect of the radio transmitters could not be discounted, but the bias was considered constant between the two groups of radio-marked females.

Females paired with a new partner did not show any migration delay and had similar breeding success to females paired with their original males. Although all of the breeding parameters taken separately were not significantly different between the two groups of females, values for all of them but brood success in fall, departure and arrival dates were constantly lower in newly-formed pairs. Therefore, we cannot rule out the possibility that these cumulative effects may have resulted in a lower fitness for females with a new partner compared to those paired with their original male. Unfortunately this could not be evaluated, in part due to small sample sizes. The power of our tests indicated that it is very difficult to detect small differences that could make a difference in reproductive output.

Nevertheless, our results contrast with those found in the literature. For instance, mate changes in Kittiwakes (*Rissa tridactyla*) delayed clutch initiation (Coulson 1966). It has also been reported for Manx shearwater, gannet and barnacle goose that coordination between mates for parental care was influenced by experience of the individuals and the pair itself (Brooke 1978, Nelson 1966, Forslund and Larsson 1992). Moreover, Forslund and Larsson (1992) concluded that reduction in reproductive success after mate change in barnacle geese was more likely due to the lower average age or breeding experience of new partners than to the benefits of breeding experience with one particular partner. Cooke *et al.* (1981) observed a lower clutch size for females paired with a new mate compared to those paired with their original mate but did not find a decrease in the number of goslings leaving the nest. They believed that the observed reduction in clutch size of remated females occurred because mate change took place more often after the first breeding attempt. Consequently, newly formed pairs include a high proportion of second time breeders. Considering that it is not before the third breeding attempt that maximum egg production is achieved, it is thus normal to observe clutch size reduction for females paired with a new mate. This corresponds to results of Ens *et al.* (1993), who found that new oystercatcher pairs were less successful that older pairs. However, Ens *et al.* (1993) said that lower reproductive success of newly formed pairs cannot be attributed to an effect of mate change on success when using matched-pair comparisons. These tests allowed them to compare the reproductive success of each pair between their first and second breeding attempt.

We also observed that pairing could occur just prior to the nesting season. This confirms the observations of Owen *et al.* (1988) who noted that pair formation could occur during any moment of the year. Owen *et al.* (1988) and Cooke *et al.* (1975) suggested, that it is normal to observe a peak of re-pairing during winter simply because most mortality occurs in late summer and fall. Although even if females can paired with a new partner at the onset of the breeding season, only a small percentage of the newly mated females were able to breed successfully. Therefore, the effect of pair break-ups in greater snow geese attributed to spring hunting may have some influence on the dynamics of this expanding population.

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# CONCLUSION GÉNÉRALE

Les taux élevés de séparation que nous avons observés chez la Grande Oie des neiges ne sont probablement pas attribuables à une stratégie de rappariement ni au stress des captures massives ou aux relâchés non-groupés, mais plutôt à un effet des colliers munis de radio-émetteurs. Ce type de collier provoque des modifications comportementales chez les femelles, engendrant du même coup des divorces. En effet, les femelles munies de colliers émetteurs passent beaucoup plus de temps à manipuler leur collier, à se reposer et tendent à passer moins de temps à s'alimenter que les femelles équipées de colliers conventionnels. Toutefois, ces changements comportementaux semblent s'atténuer avec le temps. Dès le printemps suivant le marquage, nous n'observons aucune différence comportementale entre les femelles munies de colliers émetteurs et celles équipées de colliers conventionnels où encore celles ne portant pas de collier.

Nous avons également observé une diminution du succès reproducteur des femelles munies de colliers émetteurs. En effet, les paramètres de reproduction tels la date d'initiation des nids, la taille de ponte ainsi que le succès de nidification de ces femelles sont tous plus faibles par rapport aux résultats du groupe témoin. De plus, deux ans après le marquage, la reproduction de ces femelles semble toujours négativement affectée par la présence de ces colliers. Ces résultats concordent avec ceux de Schmutz et Morse (2000) qui observaient une diminution de la taille de ponte chez les femelles équipées de colliers émetteurs et/ou de colliers conventionnels. Par contre, les femelles munies de colliers émetteurs ne démontrent pas de délais de migration et présentent des paramètres de reproduction semblables, qu'elles soient pairées avec leur mâle original ou avec un nouveau partenaire. Toutefois, pour la plupart des paramètres de reproduction, les femelles en couple avec leur partenaire original obtiennent des résultats légèrement supérieurs. Pris séparément, ces paramètres ne diffèrent pas significativement entre les deux groupes, mais, à la fin du cycle de reproduction, le cumul de leurs effets pourrait conduire à une diminution du «fitness» des femelles en couple avec un nouveau partenaire.

Malgré tout, ces colliers semblent donner de meilleurs résultats que les harnais. Nous avons obtenu un taux de séparation de 36% chez les femelles munies de colliers émetteurs, tandis que Ward et Flint (1995) ont observé 90% de séparation pour les bernaches cravants munies de radio attaché avec un harnais.

Nous croyons aussi que l'utilisation d'implants, alternative suggérée chez les canards (Rotella *et al.* 1993), n'est pas une technique applicable chez les oies. L'utilisation d'implants munis d'antennes externes, nécessaires pour avoir une bonne portée, n'est pas adéquate, car les oies tireraient sur l'antenne, ce qui causerait des blessures.

Par conséquent, les radio-émetteurs fixés sur des colliers représentent une alternative intéressante, mais imparfaite, qui nécessite toutefois des améliorations. C'est pourquoi nous recommandons tout d'abord de diminuer le poids des colliers munis de radio-émetteur à moins de 2,5% de la masse corporelle des oiseaux. En deuxième lieu, nous recommandons de réduire la longueur des antennes, car elles semblent être une source importante de d'agacement pour les oies, particulièrement au moment du toilettage. Un compromis doit donc être fait entre les effets que le marqueur (radio-émetteur) a sur l'oiseau et sa performance en terme de longévité (poids de la batterie) et de portée du signal (longueur de l'antenne). Les chercheurs devraient donc prendre en considération et être conscients de ces effets afin de mieux interpréter leurs résultats.

Finalement, en ce qui concerne la chronologie de rappariement, nos résultats démontrent que la formation d'un couple peut se faire tout juste avant la saison de reproduction. Le fait qu'une femelle puisse remplacer son partenaire tard au printemps vient appuyer les observations d'Owen *et al.* (1988) qui avaient noté que les couples pouvaient se former à n'importe quel moment de l'année. Ils croient qu'il est toutefois normal d'observer un plus fort pourcentage de rappariement durant l'hiver parce que la plupart des mortalités surviennent durant la fin de l'été ainsi qu'au cours de l'automne. D'autre part, même si les femelles peuvent se rapparier tout juste quelques semaines avant la saison de reproduction, seul un faible pourcentage des femelles qui sont seules au printemps sont à même de nicher avec succès. Par conséquent, les bris de couples de Grande Oie des neiges causés par une chasse printanière pourrait donc avoir un certain effet sur la dynamique de cette population en expansion.

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