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Source: *The Auk*, Vol. 119, No. 3 (Jul., 2002), pp. 676-684
Published by: American Ornithologists' Union
Stable URL: http://www.jstor.org/stable/4089966
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The Auk 119(3):676–684, 2002

RELATIONSHIP AMONG BREEDING, MOLTING, AND WINTERING AREAS OF MALE BARROW'S GOLDENEYES (*BUCEPHALA ISLANDICA*) IN EASTERN NORTH AMERICA

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ABSTRACT.—Little is known of the eastern North American population of Barrow's Goldeneyes (*Bucephala islandica*), which was recently listed as "of special concern" in Canada. In 1998 and 1999, we marked 18 adult males wintering along the St. Lawrence River, Québec, with satellite transmitters to document their breeding, molting, and wintering distribution and phenology, and to describe timing and routes of their spring, molt, and fall migrations. Thirteen males moved inland from the St. Lawrence River to breed; the spring migration averaged 5.9 days, and birds arrived on breeding areas on average 9 May. All breeding areas were inland, on the north shore of the St. Lawrence River estuary and gulf. Breeding areas averaged 64.8 km from the St. Lawrence corridor. Males stayed on their respective breeding area a mean of 34.5 days, and left on average 11 June. Twelve males were tracked to their molting areas, one of which stayed on its wintering area until 5 June and flew directly to its molting area. Their molt migration averaged 18.6 days, and the mean arrival date on molting areas was 30 June. All molting areas were located north and averaged 986 km from breeding areas. Four males molted in Hudson Bay, four in Ungava Bay, two in northern Labrador, one on Baffin Island, and one inland, near the Québec–Labrador border. The mean length of stay on the molting areas was 105.3 days, and the mean date of departure from molting areas was 4 October. All goldeneyes for which the radio still functioned during fall migration returned to winter in the St. Lawrence River estuary, on average 6 November. Our results refute the idea that the main breeding area of the eastern North American population of Barrow's Goldeneyes is located in northern Québec and Labrador and rather indicate that it is in the boreal forest just north of the St. Lawrence River estuary and gulf. They also indicate that Barrow's Goldeneye males undertake a genuine molt migration, and highlight the importance of molting areas because birds stayed there approximately four months each year. *Received 13 June 2001, accepted 15 March 2002.*

RÉSUMÉ.—On connaît peu de chose de la population du Garrot d'Islande (*Bucephala islandica*) de l'est de l'Amérique du Nord, qui fait partie des espèces 'préoccupantes' du Canada. En 1998 and 1999, nous avons marqué à l'aide d'émetteurs satellites 18 mâles adultes du Garrot d'Islande le long du fleuve Saint-Laurent, Québec, afin de documenter leurs déplacements entre les aires d'hivernage, de nidification et de mue. Treize garrots se sont déplacés à l'intérieur des terres pour nicher et tous les secteurs de nidification se trouvaient sur la rive nord de l'estuaire et du golfe du Saint-Laurent. La migration printanière a duré en moyenne 5,9 jours et les oiseaux ont atteint les aires de nidification en moyenne le 9 mai, lesquelles se trouvaient à 64,8 km en moyenne du Saint-Laurent. Les garrots sont demeurés sur les aires de nidification en moyenne 34,5 jours et les ont quittées en moyenne le 11 juin. Douze garrots ont été suivis jusqu'à leur aire de mue, dont un est demeuré sur l'aire d'hivernage jusqu'au 5 juin pour ensuite se rendre directement à son aire de mue. Leur migration de mue a duré en moyenne 18,6 jours, et la date d'arrivée moyenne aux aires de mue fut le 30 juin. Toutes les aires de mue se trouvaient au Nord, à 986 km en moyenne des aires de nidification. Quatre mâles ont mué à la baie d'Hudson, quatre à la baie d'Ungava, deux dans le nord du Labrador, un à la Terre de Baffin et un près de la frontière Québec-Labrador. Les garrots sont demeurés sur les aires de mue 105,3 jours en moyenne et les ont quittées en moyenne le 4 octobre. Tous les oiseaux dont les émetteurs ont fonctionné jusqu'à l'automne sont retournés, en moyenne le 6 novembre, le long du Saint-Laurent pour y passer l'hiver. Nos résultats réfutent la thèse selon laquelle le nord du Québec et du Labrador constituerait

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l'aire principale de nidification du Garrot d'Islande dans l'est de l'Amérique du Nord et montrent plutôt que cette population niche dans la forêt boréale qui s'étend au nord de l'estuaire et du golfe du Saint-Laurent. Ils mettent aussi en évidence l'importance des aires de mue, situées dans l'Arctique, où les mâles se concentrent et demeurent environ quatre mois par année.

BARROW'S GOLDENEYES (*Bucephala islandica*) have been studied in western North America (see Eadie et al. 2000), where most of the world population (approximately 150,000–200,000 birds) is distributed, and in Iceland (Gardarsson 1978; Einarsson 1988, 1990), where a small (approximately 2,000 birds) resident population is found (Scott and Rose 1996). However, little information has been collected in eastern North America, where a small (approximately 4,500 birds) threatened population winters along the St. Lawrence River, Québec, and to a lesser extent in the Atlantic provinces and Maine (Reed and Bourget 1977; Savard 1990, 1996; Savard and Dupuis 1999; Robert et al. 2000a). Indeed, the eastern North American population of Barrow's Goldeneye was recently designated as "of special concern" by the Committee on the Status of Endangered Wildlife in Canada (2001) because of threats posed by oil spills, logging, fish introductions in breeding lakes, hunting, and contamination by toxic substances (Robert et al. 2000a). Breeding locations have recently been identified in eastern North America (Robert et al. 2000b); however, the extent of the breeding range of the population and other aspects of its distribution and ecology are still largely unknown.

Satellite telemetry has been used in recent years to obtain detailed information on movements of Mergini such as the Spectacled Eider (*Somateria fisheri*) and the Harlequin Duck (*Histrionicus histrionicus*), and contributed to major discoveries (Petersen et al. 1995, 1999; Brodeur et al. 2002) that would not likely have been made by conventional studies. As part of our investigations of Québec's birds at risk, we implanted 18 adult male Barrow's Goldeneyes wintering along the St. Lawrence River with satellite transmitters. Our objectives were to (1) document their breeding and molting distribution and phenology, (2) describe the timing and routes of their spring, molt, and fall migrations, and (3) document their movements along the St. Lawrence River corridor in winter.

METHODS

Capture and satellite telemetry.—Using decoys and two 18 m mist nests set side by side over water (Burns et al. 1995, Robert et al. 2000b), we captured 18 adult male Barrow's Goldeneyes at three important concentration areas along the St. Lawrence River estuary, 165–365 km downstream from Québec City, Québec, Canada. Three birds were captured and instrumented with satellite transmitters on 21–22 February 1998 at Baie des Rochers (47°57′N, 69°48′W); four on 7–10 April 1998 and three on 19–21 April 1999 at Pointe Mistassini (49°17′N, 67°56′W); and four on 17–18 November 1998 and four on 15–16 April 1999 at Anse à Capelans (48°20′N, 68°51′W). We attached transmitters following an implant technique adapted from Korschgen et al. (1996) (Fitzgerald et al. 2001). Average time between capture and release after surgery was 6 h 42 min ± 1 h 43 min (range = 3 h 40 min–8 h 55 min, n = 17). The surgical procedure, from incision to closure, was completed on average in 42 ± 7 min (range = 28–56, n = 17). Birds were released in the wild on average 2 h 09 min ± 57 min (range = 1 h 15 min–4 h 09 min, n = 17) after the end of anesthesia. To avoid long-term stress, birds were not held overnight. Although we were not able to monitor each duck after its release, we observed no abnormal behavior attributable to the surgery.

We used Argos PTT-100 implant transmitters (Microwave Telemetry, Columbia, Maryland) that have been described elsewhere (Robert et al. 2000b). They weighed 50–52 g, and represented 4.7% or less of the birds' body mass at the time of surgery (range = 4.0–4.7, n = 18). All transmitters were programmed to transmit with a 60 s pulse rate on different duty cycles permitting the limited battery power (~800 h) to be conserved for the phases of the study that were of most interest. Transmitters implanted in February and April 1998 (transmitters implanted in April 1998 were started in February 1998) were set to transmit on a 7 h on, 48 h off cycle for the first 56 days; followed by a 6 h on, 24 h off cycle for 70 days (to document spring migration, breeding areas, and molt migration); then 7 h on, 72 h off cycle (to locate molting areas). All transmitters implanted in November 1998 were set to examine winter movements: two were set to always transmit on a 4 h on, 4 h off cycle and two on a 6 h on, 48 h off cycle. Males implanted in April 1999 had their transmitters programmed on a 5 h on, 24 h off cycle for the first 83 days (to doc-

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ument spring migration, breeding areas, and molt migration); on a 6 h on, 96 h off cycle for the following 103 days (to locate molting areas); on a 6 h on, 48 h off for the following 47 days (to document fall migration); then on a 6 h on, 72 h off cycle (for winter). Each transmitter was equipped with sensors to measure internal temperature of the unit (i.e. internal temperature of the bird), battery voltage, and animal activity. The activity sensor reading increments by 1 each time the transmitter (i.e. the bird) moves, so a static reading either indicates that the bird lost its transmitter, which is unlikely but possible when using implants (Mulcahy et al. 1999), or died.

We monitored bird movements using the Argos Data Collection and Location System in Landover, Maryland. The Argos satellite-based tracking system is described in detail in Harris et al. (1990) and Service Argos (1996). Both standard (location classes [LC] 3, 2, 1, and 0) and auxiliary location (LC A and B) processing services (Service Argos 1996) were used in this study. We did not consider multiple locations recorded within a single (4–7 h) transmission period as independent, so we selected for each individual one location per transmission period to describe its position. We selected the location with the most precise LC (3>2>1>0>A>B; without considering LC Z). If several locations were part of the more precise class, we selected the one that had the highest quality index (Service Argos 1996). If the more precise location was indexed with a "poor" LC (A or B), we selected it only if it was confirmed by standard locations (LC 3, 2, 1, and 0) obtained in previous or subsequent days.

Mapping and classification of selected locations.—Using MAPINFO 6.0 Geographic Information System software, we mapped (for each individual) all selected locations on a 1:2,000,000 digital chart. We then classified each location, based on geographic position rather than date, within one of the following categories: wintering area, spring migration, breeding area, molt migration, molting area, and fall migration. A bird was considered on its wintering area when it was located along the St. Lawrence River corridor (Robert et al. 2000a). Breeding and molting areas were identified from clusters of locations obtained from individuals. A bird was considered on its breeding area if it remained in a restricted inland area for at least 14 days, and did not travel more than 20 km between the two most distant locations (considering only LC 3, 2, and 1) obtained during that period. A bird was considered on its molting area if it remained in a restricted area for at least 21 days, and did not travel more than 52 km between the two most distant locations (considering only LC 3, 2, and 1) obtained during that period. A bird was considered migrating when sequential locations indicated movement in a single direction, and when it was located between its wintering and breeding areas (spring migration), between its breeding or wintering and molting areas (molt migration), or between its molting and wintering areas (fall migration).

Arrival and departure dates, duration of periods, and statistics.—We were not able to determine the precise date on which an individual left an area or arrived at an area because locations were usually calculated at 2–4 day intervals, due to transmitter programming. We considered that a bird migrating to an area had arrived by the first date a location was obtained from that area, whereas a bird leaving an area was considered to have departed on the day following the date a location was last obtained from that area. We calculated means of departure date from wintering areas, duration of spring migration, arrival date at breeding areas, departure date from breeding areas, duration of molt migration, arrival date at molting areas, departure date from molting areas, duration of fall migration, and arrival date at wintering areas. We tested annual differences among mean departure dates from wintering areas using Wilcoxon-Mann-Whitney U-tests (Zar 1984), as well as mean arrival dates at the breeding and molting areas. There was some suggestion that birds may have stayed on the breeding areas for a longer period in 1998 (40.8 days ± 7.1, range = 30–49, n = 5) than in 1999 (30.5 days ± 15.2, range = 14–65, n = 8) ($U = 34$, $n_1 = 5$, $n_2 = 8$, $P = 0.05$), but we detected no other annual differences (U = 13–40, $n_1 = 5$, $n_2 = 8$, $P > 0.20$). Consequently, data from 1998 and 1999 were combined. We calculated number of days during which each bird was tracked, as the difference between the capture date and the date when the last location (without considering LC Z) was obtained. We calculated distance between each breeding area and the closest shore of St. Lawrence River using the mean of all locations (considering only LC 3, 2, and 1) obtained during the breeding period. We used standard location classes to calculate duration of migrations and flight speeds.

RESULTS

We received a total of 6,034 locations, of which 2.6, 6.8, 15.0, 13.5, 15.6, 19.3, and 27.2% were of class 3, 2, 1, 0, A, B, and Z, respectively. We selected 1,352 (22.4%) of those, of which 10.2, 19.4, 26.5, 18.8, 14.4, and 10.8% were of class 3, 2, 1, 0, A, and B, respectively. Locations were received for all birds although two individuals, from which we received 73 (G16) and 87 (G15) locations, likely died three days and two months following the surgery, respectively, and never left the St. Lawrence River corridor (Fitzgerald et al. 2001). Without considering those individuals, the mean number of locations received per bird was 367 (SD = 150, range 109–565, n = 16), whereas the mean

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number of locations selected per bird was 82 (SD = 31, range 28–157, n = 16). Overall, the mean number of days during which the birds were tracked was 183 (SD = 71, range = 77–325, n = 16).

Spring migration and breeding period.—Male goldeneyes remained on their wintering area on average until 3 May ± 8.7 days (range = 20 April–21 May, n = 13). Thirteen males (G1, G2, G3, G4, G5, G6, G7, G9, G10, G11, G13, G18, and G19) moved from the St. Lawrence River inland to breed (Fig. 1). Duration of spring migration lasted on average 5.9 ± 5.4 days (range = 1–19, n = 13). Two males moved rapidly from the St. Lawrence River to their respective breeding areas. One (G4) was located on its wintering area on 21 May 1999 at 0428, and on its breeding area on 22 May 1999 at 0357, that is, 23 h 29 min later. The other (G1) migrated from the St. Lawrence River (11 May 1999, 0630) to its breeding area (12 May 1999, 1540) in 33 h 10 min or less. Average arrival date on breeding areas was 9 May ± 7.7 days (range = 27 April–22 May, n = 13).

All breeding areas were inland, north of the St. Lawrence River estuary and gulf. Two birds bred north of the Saguenay River, and all the others nested further east on the Québec North Shore from the Manicouagan River watershed to north of Natashquan (Fig. 1). Breeding areas averaged 64.8 ± 31.4 km (range = 25–137, n = 13) from the St. Lawrence corridor. Males stayed on their respective breeding area on average 34.5 days ± 13.4 (range = 14–65, n = 13), departing the breeding areas on average 11 June ± 9.7 days (range = 29 May–30 June, n = 13).

Molt migration and molting period.—Twelve males (G1, G2, G3, G4, G5, G6, G9, G10, G11, G17, G18, and G19) were tracked to their molting areas, of which one (G17), a suspected nonbreeder, stayed on its wintering area until 5 June and flew directly to its molting area (Fig. 1). The molt migration of those males lasted on average 18.6 ± 12.6 days (range = 4–47, n = 12) and their mean arrival date on molting areas was 30 June ± 14.1 days (14 June–27 July, n = 12). The mean travel time between breeding areas and coastal Hudson Bay, Ungava Bay, or Labrador was only 6.0 ± 4.5 days (range = 2–16, n = 11) and the mean arrival date in these areas was 19 June ± 9.3 days (range = 8 June–4 July, n = 11).

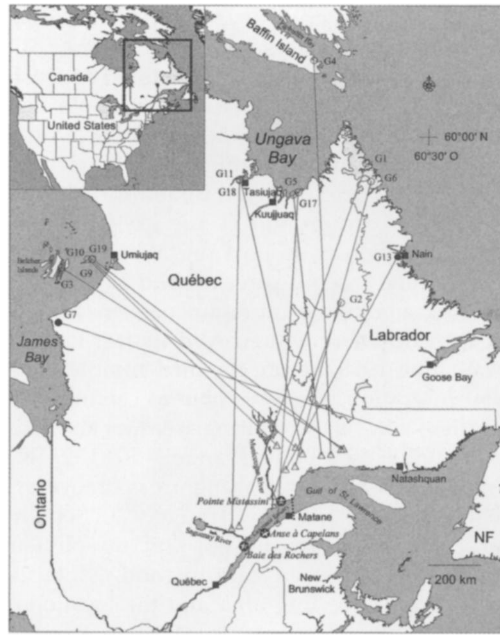

FIG. 1. Breeding and molting distribution of adult male Barrow's Goldeneyes marked with implanted satellite transmitters on their wintering area in eastern Canada, showing that birds wintering along the St. Lawrence River, Québec, breed inland along the north shore of the St. Lawrence River estuary and gulf, and molt in Arctic coastal areas far away from their breeding areas. White stars in black circles denote capture locations; black squares denote cities or villages; white triangles denote breeding areas; white circles denote molting areas; black circles denote last locations obtained from birds for which we obtained incomplete information on molt migration. The white diamond denotes last winter location obtained from a bird, probably a nonbreeder, which flew directly from its wintering area to its molting area. Black lines connect breeding and molting areas, and do not necessarily reflect migration paths. The dotted line denotes the separation between of the St. Lawrence River estuary and gulf. Each code (e.g. G1, G19) refers to a particular individual.

Molting areas were located an average of 986 ± 178 km (range = 679–1,293, n = 11) north of breeding areas. Molting areas included the Salikuit Islands (G9, G10, and G19) and the Belcher Islands (G3) in Hudson Bay; the Leaf River estuary (G11 and G18), Marralik River (G5), and Alukpaluk Bay (G17) areas in Ungava Bay; Cape White Hankerchief (G1) and Ramah Bay (G6) in northern Labrador; and Jackman Sound (G4), Frobisher Bay, on Baffin Island (Fig. 1).

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Nine of these goldeneyes molted in coastal salt or brackish waters, whereas the three others (G1, G2, and G6) probably molted on freshwater lakes. We also obtained incomplete information on molt migration for two other individuals: one (G7) migrated to northern James Bay, where it stayed inland for a month and finally died around 11 July 1999, probably before completing its molt migration. The other (G13) left its breeding area around 20 June 1998 and migrated to the Labrador coast, in the Nain area, from where we received its last location on 22 June 1998, before the bird completed its molt migration. We were able to calculate the length of stay on the molting areas for six birds: mean 105.3 ± 14.3 days (range = 87–122). The goldeneyes left their molting areas on average on 4 October ± 13.8 days (range = 12 September–23 October). We did not find any obvious relationship between capture and wintering site or local breeding area and the location of molting areas. Movements of some birds to Hudson Bay (G03, G07, G09, G10) or Ungava Bay (G11, G17, G18) were quite direct and unrelated to the breeding location of the bird (Fig. 1). One bird (G19) went to Ungava bay before moving to Hudson Bay and one (G05) to the Labrador coast before going to Ungava Bay. Three birds (G01, G04, G06) followed the northern Labrador coast before reaching their molting areas.

Fall migration and wintering.—All goldeneyes for which the radio still functioned during fall migration (G1, G6, G17, and G18) returned to winter in the St. Lawrence River estuary. Fall migration to wintering areas lasted a mean of 24.0 ± 17.9 days (range = 3–46, n = 4). Mean return date was 6 November ± 17.1 days (range = 22 October–28 November, n = 5). Barrow's Goldeneyes frequented both shores of the St. Lawrence River estuary during their wintering period, and none of them visited the Gulf of St. Lawrence.

Flight speed.—One goldeneye (G1) was located near Gagnon (51°53′N, 68°10′W), Québec, on 9 June 1999 at 2139, and near Shefferville (54°48′N, 66°50′W), Québec, on 10 June 1999 at 0202. It thus covered 365 km in 4 h 23 min (83 km h^{-1}), at night.

DISCUSSION

This study is the first to use satellite telemetry to follow Barrow's Goldeneye movements. As with other studies using that technology on sea ducks (Petersen et al. 1995, 1999; Brodeur et al. 2002, O. H. Rosenberg and M. J. Petrula unpubl. data), satellite telemetry yielded unexpected results that would have taken decades to obtain otherwise.

Spring migration and breeding period.—The spring departure phenology we observed is in accordance with information presented by Larivée (1993) and David (1996), which indicates that the frequency of detection of Barrow's Goldeneyes along the St. Lawrence corridor decreases rapidly from the end of April to the end of May. The springs of 1998 and 1999 were unusually warm (9.4°C in May 1998 and 10.8°C in May 1999, compared to a 1947–2000 mean of 6.6°C; A. Julien pers. comm.), which may have produced an earlier migration of goldeneyes towards their breeding areas than in most years. The birds that were tracked probably went inland as soon as open water appeared on the breeding grounds, that is, about two weeks before ice break-up, as is the case for Common Goldeneyes (*Bucephala clangula*; Carter 1958, Eadie et al. 1995). In most years, Barrow's Goldeneyes likely leave the St. Lawrence River estuary throughout May.

Some of the birds tracked moved rapidly from their wintering to their breeding grounds. Although little detailed information exists on the duration of Barrow's Goldeneye spring migration, Savard (1985) observed a pair on the coast of British Columbia on 12 April 1984, then on their breeding territory, 28 h later. Knowing that Barrow's Goldeneyes may fly rapidly (this study, Palmer 1976), many pairs probably get to their breeding lakes even more rapidly, particularly in Québec, where distances between the St. Lawrence River corridor and breeding areas are short.

All breeding birds were located within the breeding area described recently by Robert et al. (2000b). However, the exact limits of the breeding range of the eastern population are still largely unknown, particularly the northern and eastern limits, and the breeding range may include areas of southern Labrador and Newfoundland (S. Gilliland pers. comm.). There are also indications that Barrow's Goldeneyes breed in some areas southwest of the Saguenay River, Québec (Savard and Dupuis 1999, M. Robert pers. obs.). Nevertheless, as Robert et al. (2000b) pointed out, the breeding of Barrow's Goldeneyes in treeless Arctic environments of eastern North America is

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now questionable. Most of the historic records from northern Labrador and Québec (see Robert et al. 2000b for details) may be of molt migrants as some males tracked during this study reached their northern molting areas by mid-June.

According to Eadie et al. (2000), western Barrow's Goldeneye males leave their breeding areas in mid-June, which is similar to the mean departure date we observed (11 June). In central Ontario, most adult male Common Goldeneyes leave their breeding grounds by early to mid-June, and all males are gone by the first half of July (Eadie et al. 1995). In fact, departure from the breeding areas varied greatly between birds tracked during this study and covered most of June, indicating that males may have departed for their molting area gradually rather than having aggregated in large numbers prior to migration.

Molt migration and molting period.—The males we tracked underwent what Salomonsen (1968) described as a "genuine molt migration." From their breeding area they traveled hundreds of kilometers north—away from their wintering area—and gathered at molting sites. Sea ducks are well known for their extensive molt migrations (Salomonsen 1968, Owen and Black 1990), often in the direction of wintering areas (see Joensen 1973, Frimer 1994, Robertson and Goudie 1999). The origin of the molt migration we described may be linked to the distribution of Barrow's Goldeneye during the Late Pleistocene, which had a major effect on the present day diversity and distribution of many extant species (Ploeger 1968, Avise and Walker 1998). Indeed, the presence of a ice-free refuge on the Newfoundland bank (Ploeger 1968) or elsewhere along the southern part of the ice sheet may explain the latitudinal migration of Barrow's Goldeneyes (this study) and Harlequin Ducks (Gilliland et al. 2002, Brodeur et al. 2002) wintering in eastern North America.

Barrow's Goldeneyes were not known to undertake the type of molt migration described in this study. In Iceland, males molt in areas adjacent to breeding sites (Gardarsson 1978, Hagemeijer and Blair 1997). In western North America, some males molting in northwest Yukon and northeast Alaska winter along the coast of Alaska (van de Wetering 1997), whereas the molting location of males breeding in central British Columbia is still unknown (Eadie et al. 2000). However, the clear northward postbreeding movements by males tracked during this study suggest that some of the goldeneyes molting in the Yukon or Alaska may well originate from British Columbia. As for Common Goldeneyes, in some areas they probably undertake a molt migration similar to the one we have described here (Salomonsen 1968, Eadie et al. 1995), but they are also known to undergo a southward molt migration towards wintering areas in some parts of Europe (Jepsen and Joensen 1973, Jepsen 1973). In eastern North America, Todd (1963) reported large numbers of Common and possibly Barrow's goldeneyes in Hudson and Ungava bay, and assumed that those individuals were nonbreeders or postbreeding birds attracted by the abundant food supply and remaining there to molt. Todd (1963) also reported a raft of 1,500 molting goldeneyes at the head of Nain Bay, Labrador, of which nearly half were Barrow's Goldeneyes. Our satellite tracking confirmed those molting areas and indicated that the Barrow's Goldeneyes molting there are (at least partly) those wintering in the St. Lawrence River estuary and breeding in Québec.

Segregated molt migration according to age and sex has been documented in several species of sea ducks (Herter et al. 1989, Joensen 1973, Pehrsson 1975). One male (G17) went directly from its wintering to its molting site. That male may thus have been an unpaired male, and although this behavior may be typical of immature and of unpaired males (Salomonsen 1968), it has to be interpreted with caution due to sample size. In British Columbia, some unpaired males are present on the breeding areas but usually frequent larger lakes and stay in groups (Savard 1991). In Québec, groups of immature and adult unpaired males have been observed in late May along the St. Lawrence River estuary, but none have been seen on the breeding areas surveyed to date (M. Robert unpubl. data).

Our results clearly highlight the importance of molting areas for male Barrow's Goldeneyes because they spend three to four months at these sites, that is, a much longer period than the mean length (31 days) of the flightless period associated with wing molt (van de Wetering and Cooke 2000). Indeed they reach their molting areas well before their flightless period, which probably peaks in August as in northern Yukon (van de Wetering and Cooke

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2000), and leave them well after having regained their flight capabilities. Initially we expected to locate few molting sites for this population estimated to comprise only about 2,000 adult males (Robert et al. 2000a). Rather, we located a minimum of eight molting sites quite dispersed throughout the Arctic, which indicates either that few individuals congregate in each site or that the eastern North American population of Barrow's Goldeneyes may comprise more individuals than previously estimated. We were able to survey the two Ungava Bay molting areas on 9–10 July 2000; we confirmed the presence of 282 male goldeneyes in one area of the Leaf River estuary, of which at least 90% were Barrow's Goldeneyes, and counted 3,158 goldeneyes along 94 km of shoreline east of Kuujjuak, in the Marralik River and Alukpaluk Bay areas, which were mostly Common Goldeneyes (M. Robert pers. obs.). That suggests that Barrow's and Common goldeneyes may use the same areas during their molting period, as they apparently do in the Nain Bay area (Todd 1963), and that species-specific surveys of molting goldeneyes in northern Québec and Labrador should be done to better estimate the total number of each species molting in those areas.

Little is known of the type of habitats used by molting Barrow's Goldeneyes. In the Yukon, they use shallow productive freshwater lakes (van de Wetering 1997). Common Goldeneyes in Denmark molt in brackish waters of fjords as well as in coastal lakes (Salomonsen 1968, Jepsen 1973). Danish molting areas are characterized by shallow productive waters surrounded by open waters without tall marginal vegetation and protected against disturbance and predation (Jepsen 1973). Freshwater lakes are the main molting areas for females (Jepsen 1973). Barrow's Goldeneyes tracked during this study molted in coastal saltwater, in brackish waters at the mouth of large rivers, and on freshwater lakes. Although specific habitats used by molting individuals in northern Québec and Labrador have yet to be described, the survey conducted in Ungava Bay in July 2000 revealed that goldeneyes used rocky foreshores similar to those used in winter in the St. Lawrence River estuary (M. Robert pers. obs.).

Wintering period.—All individuals tracked during this study were captured along the St. Lawrence River corridor, which is the major wintering area for the eastern North American population of Barrow's Goldeneyes (Reed and Bourget 1977, Savard 1990, Robert et al. 2000a). According to Larivée (1993) and David (1996), some Barrow's Goldeneyes are usually back along the St. Lawrence River corridor in early October, but most return to the St. Lawrence from late-October onwards, which corresponds to our results. Although few birds were tracked during the winter months, our study indicates that Barrow's Goldeneyes winter mainly along the St. Lawrence River estuary, because none of the birds tracked visited the Gulf of St. Lawrence. However, our results also indicate that birds may move considerably within the St. Lawrence River estuary itself during their wintering period, particularly between the south and north shores of the estuary in relation to ice conditions. Between late December and early March, the south shore of the St. Lawrence estuary is unavailable for goldeneyes, being entirely covered by ice due to prevailing winds and currents (Anonymous 1993, Fortin et al. 1996). That contrasts with the north shore which has areas that remain ice free all winter (Canadian Ice Service 1999), providing feeding opportunities for goldeneyes.

Conclusion.—Satellite telemetry permitted the identification of breeding, molting, and wintering areas used by Barrow's Goldeneyes in eastern North America. This study supports the idea that the St. Lawrence River estuary is an important wintering area for the eastern North American population, and suggests that the main breeding area for those birds is located in the boreal forest just north of the St. Lawrence River estuary and gulf rather than in northern Québec and Labrador. Our results indicate that Barrow's Goldeneye adult males undertake a genuine molt migration, and highlight the importance of molting areas as males stay there approximately four months each year. They also suggest that even if some Barrow's Goldeneyes molt on freshwater lakes near the littoral zone, most males frequent the brackish waters of estuaries similar to their wintering habitat. Although this study yielded detailed information on Barrow's Goldeneye distribution and movements, more birds from a greater number of wintering or molting areas—in particular females and subadults—will have to be fitted with satellite transmitters to

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fully understand the movement patterns of this species in eastern North America.

Acknowledgments

This study was funded by the Species at Risk Division of the Canadian Wildlife Service (Environment Canada, Québec Region). We also thank the U.S. Department of the Interior, Fish and Wildlife Service, and the Saguenay-St. Lawrence Marine Park (Parks Canada) for their financial contribution. We express our sincere appreciation to Dr. G. Fitzgerald, from Union québécoise pour la réhabilitation des oiseaux de proie, whose surgical expertise made this study possible. Dr. J. Tremblay, A. Van Wettere, and S. Plourde also provided invaluable assistance with surgeries. Thanks to C. Marcotte, A. Bourget, F. Baillargeon, D. Bourget, P. Brousseau, A. Desrosiers, G. Falardeau, O. Mathieu, R. McNicoll, and F. Shaffer for their assistance in capturing birds, often under difficult conditions. M. Bélanger, H. Holmes, and P. Lavoie, from Bic Provincial Park, and R. Desbiens, from Baie-des-Rochers, graciously provided technical support during field work. Our special thanks to P. Howey, from Microwave Telemetry, for his continuous assistance regarding transmitters, and to S. Brodeur, whose satellite tracking of Harlequin Ducks made us believe that satellite telemetry would be a feasible way of getting new insights on the eastern North American population of Barrow's Goldeneyes. Thanks to I. Mackey and R. J. Hughes for revising the English, and to P. Boveng and J. E. Thompson for providing helpful comments on an earlier version of the manuscript.

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Associate Editor: W. Hohman

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