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Discovery of Important Postbreeding Sites for Barrow's Goldeneye in the Boreal Transition Zone of Alberta

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Abstract.—Sites where Barrow's Goldeneye (*Bucephala islandica*) undergo remigial molt and fall staging are poorly known, with only two major sites documented in Alaska and the Yukon Territory. Satellite telemetry, aerial surveys and ground surveys were used to identify previously unknown molting and fall staging areas in the Boreal Transition Zone (BTZ) of northern Alberta. Of 816 wetlands surveyed between 2004 and 2006 in the BTZ, 40-45% (105-127 lakes annually) had molting goldeneyes. Of these, 1.3-3.3% were used by large aggregations of goldeneyes (>100 birds). Two wetlands, Cardinal and Leddy Lakes, were particularly important, with an estimated 5,000-7,000 Barrow's Goldeneyes, primarily adult males, using these sites during remigial molt and fall staging. Birds used these sites up to five months or over one-third of their annual cycle. Half of adult males marked with satellite transmitters at a breeding area in interior British Columbia used Cardinal Lake for postbreeding activities. Discovery of these sites represents some of the largest concentrations of molting Barrow's Goldeneyes in North America, and the only major molting sites currently known for the intermountain breeding portion of the western population. Protection of Cardinal and Leddy Lakes, and other significant molting and staging sites within the BTZ, should be a priority conservation effort for this species.

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Key words.—Alberta, annual cycle, Barrow's Goldeneye, British Columbia, *Bucephala islandica*, remigial molt, Riske Creek, satellite telemetry, staging.

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Waterfowl (*Anatidae*) undergo a complete and simultaneous remigial molt, which typically renders individuals flightless for 20 - 40 days (Hohman *et al.* 1992). A wide range of behavioral and physiological adaptations have been described to accommodate risks and constraints associated with flightlessness and costs of feather synthesis including: reduced activity (Panek and Majewski 1990; Adams 2000), modified and/or selective foraging behavior (Ankney 1979; Owen and Ogilvie 1979; Murphy and King 1987), and reduction or redistribution of body mass and nutrient reserves (Thompson and Drobney 1996; Brown and Saunders 1998). Choice of an appropriate molt site is presumably important to reduce risks associated with simultaneous remigial molt.

Following the breeding season, waterfowl in the northern hemisphere often migrate to specific molt sites, which may be well outside of their core breeding range (Salomonsen 1968). Molt migration likely provides important benefits, including access to larger and more drought resistant wetlands, reduced human disturbance, abundant food and low predator densities relative to breeding areas (Zicus 1981; Derksen *et al.* 1982; Madsen and Mortensen 1987).

Identification of molting sites has important conservation implications. First, because molting waterfowl tend to be highly congregated at relatively few sites, each site may support a significant proportion of a population. Second, because molting waterfowl are flightless, they are susceptible to human disturbance or catastrophic events, so protection of these sites from potentially negative anthropogenic influences is important. Third, some waterfowl species also use their molting sites during fall staging, remaining on the same wetland system for one-third or more of their annual cycle (Gilliland *et al.* 2002; Savard *et al.* 2007; Oppel *et al.* 2008). Finally, by documenting areas used by large aggregations of molting birds, characteristics of molt sites can be determined and those attributes used to identify other potential sites to survey and monitor. Despite the importance of molt site identification for waterfowl conservation, there are many species for which this information is not available. In particular, this is true for sea ducks (*Mergini*), many of which have shown long-term and broad-scale population declines. Significant effort is currently being directed at understanding when and where bottlenecks in the annual cycle of these species may occur (Sea Duck Joint Venture Management Board 2008).

To date, only two major molting sites of Barrow's Goldeneyes (*Bucephala islandica*) have been identified in western North America: Ohtig Lake, Alaska supporting around 5,000 molting birds (King 1963) and Old Crow Flats, Yukon Territory supporting approximately 7,000 molting birds, primarily males (Van de Wetering 1997). Numbers of Barrow's Goldeneye in western North America have been estimated between >125,000 (Bellrose 1980) and <200,000 (Eadie *et al.* 2000) so molting areas for the majority of these birds have not been determined, particularly for those that occur in more southern parts of their breeding and wintering ranges (e.g. British Columbia and Washington). Based on evidence from aerial and ground surveys, satellite telemetry and captures of molting individuals, we document the discovery of previously unrecognized molting sites for Barrow's Goldeneyes in the Boreal Transition Zone (BTZ) of Alberta.

METHODS

Study Area

The Boreal Transition Zone (BTZ) of western Canada extends from southeastern Manitoba through northwestern Alberta to the Rocky Mountains. A rapidly changing region, the BTZ includes the southern tier of ecoregions in the Boreal Plain ecozone which was historically comprised of mixed boreal forest and native grasslands, interspersed with abundant wetlands and lakes. The BTZ is increasingly being converted to agriculture and other land uses (Hobson *et al.* 2002; Epners *et al.* 2010). Cardinal Lake (56°14'N, 117°44'W), also referred to as Lac Cardinal, is a large (50 km^2) shallow lake located in the BTZ of northwestern Alberta. The basin rarely exceeds a depth of 2 m, has a primarily sand and gravel bottom, and is hypereutrophic. Leddy Lake is a small (4 km^2), open fen located approximately 25 km NE of Cardinal Lake. The basin is shallow (<2 m), with a primarily muddy substrate, dense submerged vegetation mat throughout most of the lake, and is mesotrophic.

Aerial Surveys

Fixed-wing aerial surveys were conducted over 59,200 km^2 of the Boreal Transition Zone of Alberta from 2004 to 2006 (Fig. 1). In the absence of detailed wetland inventory data, these surveys were focused in pre-established blocks within the BTZ landscape that had relatively high wetland densities based on analysis of digital versions of 1:50,000 scale National Topographic Survey (NTS) maps. Each basin visible on the 1:50,000 NTS map within the survey blocks (Fig. 1) was completely surveyed at least three times from mid-July through late August. Surveys were conducted at least one week apart to help account for interspecific variation in timing of remigial molt. Additionally, most sites heavily used by waterfowl were surveyed during more than one year to better understand annual variation in use. While timing of these surveys coincided almost perfectly with the early-July through mid-September timing of remigial molt for Barrow's Goldeneyes documented in the Yukon (Van de Wetering and Cooke 2000), they were designed to document broad-scale waterfowl use of the region and did not specifically target any species. Further, because of difficulties differentiating Barrow's and Common Goldeneyes (*Bucephala clangula*) during aerial surveys, observed individuals of both species were recorded as "goldeneyes". However, site-specific ground surveys were subsequently conducted at several wetlands and were used to estimate the proportion of each species present.

Because only wetlands visible on a 1:50,000 scale NTS map were surveyed, not all suitable molting habitats were included in the surveys. Furthermore, deeper, fish-bearing lakes were excluded from these surveys given that they seldom provide significant molting habitat for waterfowl in the BTZ (Epners *et al.* 2010). Surveys included approximately 250 to 300 wetlands annually, including two shallow lakes that are particularly relevant to this paper: Cardinal Lake and Leddy Lake.

Satellite Telemetry

Adult male and female Barrow's Goldeneyes were captured and implanted with satellite transmitters (26 g

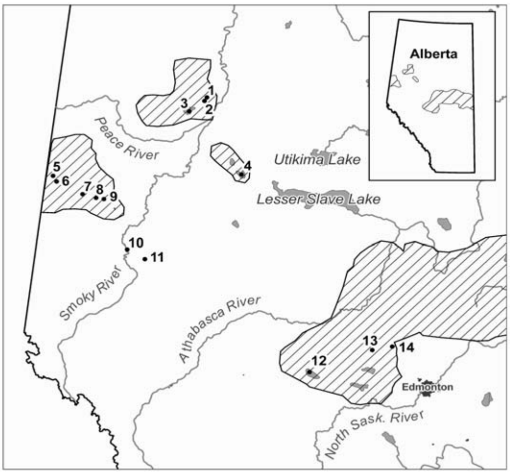

Figure 1. Location of Boreal Transition Zone wetlands and shallow lakes in Alberta of particular importance to molting goldeneyes (ha; max count goldeneyes): 1. Leddy Lake (350 ha; 583), 2. Unnamed lake (58 ha; 103), 3. Cardinal Lake (5011 ha; 4,122), 4. Winagami Lake (4682 ha; 284), 5. Ray Lake (130 ha; 130), 6. Powell Lake (105 ha; 158), 7. Bush Lake (421 ha; 101), 8. Cutbank Lake (184 ha; 104), 9. Bear Lake (3217 ha; 483), 10. Sandhill Lake (445 ha; 266), 11. Tawakwato Lake (350 ha; 344), 12. Chip Lake (7471 ha; 2178), 13. Majeau Lake (1550 ha; 125), 14. George Lake (469 ha; 157). Sites were discovered through fixed-wing aerial surveys conducted from 2004-2006. Hatched areas on the figure indicate survey blocks with relatively high wetland densities that were surveyed during the molting period (mid-July through late August). Some molting sites occurred outside of larger survey landscapes, but were included based on evidence that they could be important to molting waterfowl.

or 38 g, Microwave Telemetry Inc.) at a breeding area and a wintering area in southern British Columbia. The breeding area, near Riske Creek (52°5'N, 122°30'W), is comprised of numerous small, shallow wetlands and is recognized as a high-density breeding site for Barrow's Goldeneyes (Savard 1986; Thompson 1996; Evans 2003). In 2006-2008 we captured adult males during the breeding period (May) using a decoy and partially submerged mist net. Adult females were captured during the brood-rearing period in 2008 using drive traps. We implanted 20 adult males and nine adult females from the Riske Creek breeding area. On a coastal wintering site in Indian Arm, British Columbia (49°19'N, 122°55'W), we captured Barrow's Goldeneyes in February 2007 using floating mist nets and decoys (Kaiser *et al.* 1995). We implanted satellite transmitters into three adult males and five adult females. All transmitter implant surgeries were conducted by a certified veterinarian following standard procedures (Korschgen *et al.* 1996; Mulcahy and Esler 1999).

Signals from implanted transmitters were obtained from the Argos satellite data system (CLS America). Transmitters were set to automatically transmit locations for two to six hours every three to four days. We identified molt sites as locations where a bird remained for ≥40 days between 1 July-30 September for males and 1 August-30 September for females (Van de Wetering and Cooke 2000; D. Hogan unpublished data). In one case, a male migrated to Cardinal Lake and remained there for 13 days before its transmitter failed. We classified Cardinal Lake as the molt site for this individual because it was logical in relation to the timing and pattern of migration.

Intensive Ground Surveys

Based on previous observations from aerial surveys and data from satellite telemetry (see Results, below) suggesting that Cardinal Lake was an important molting and staging site for Barrow's Goldeneye, we conducted ground-based surveys to determine numbers and species composition of goldeneyes using Cardinal and Leddy Lakes. Weekly counts were conducted using spotting scopes throughout the molting and staging periods from early June to November in 2009 and 2010. The counts were conducted in twelve discreet segments located around Cardinal Lake. The segments were chosen to cover as much of the lake area as possible without overlap; some portions of the lake were not regularly surveyed due to difficult accessibility, but we confirmed on multiple occasions that they tended to have few birds (<100).

Despite relatively modest and sporadic use of Leddy Lake by Barrow's Goldeneyes from 2004 through 2006, a relatively large number of birds molted at this site in 2009 and this led to a ground survey program. Surveys were conducted from a single point on the shoreline using spotting scopes, which provided a view of most of the lake area. Total numbers of Barrow's Goldeneyes observed were recorded for each survey.

Age/Sex Ratios

We captured Barrow's Goldeneyes during remigial molt on both Cardinal and Leddy Lakes on 29 occasions in 2009 and 2010, using drive-trapping methods (Van de Wetering 1997). Age and sex ratios were derived from total counts of each cohort from the capture data for each year. Sex was determined by cloacal examination (Hochbaum 1942) and plumage characteristics (Carney 1983) and age class was indicated by bursal depth (Mather and Esler 1999). Age class was designated as either second-year (SY; i.e. one to two months beyond the first year after hatching, bursa >10 mm) or after-second-year (ASY, bursa ≤ 10 mm).

RESULTS

Aerial Surveys

A total of 816 wetlands were surveyed between 2004 and 2006 in the BTZ of Alberta. Of these, 40 to 45% of wetlands surveyed annually (105-127 lakes) had molting goldeneyes. However, only a small proportion of surveyed sites were used by large aggregations of goldeneyes (≥100 birds) in any given year (2004 = 1.3%, 2005 = 2.9%, 2006 = 3.3%). Of these few sites, Cardinal Lake consistently received the highest use with molting goldeneye counts ranging from 3,105 to 4,122 birds over the three years. Chip Lake, a large, shallow lake system in west-central Alberta consistently showed the second highest use by molting goldeneyes between 2004 and 2006. Leddy Lake goldeneye counts were the third highest in two of the three years, and ranged from 96 to 568 (Table 1).

Concurrent ground surveys of goldeneyes at Cardinal and Leddy Lakes indicated that Barrow's Goldeneyes consistently comprised ≥90% of the total goldeneyes present during remigial molt. While not formally counted, ground observations at Chip Lake also suggested that the majority of goldeneyes using this site during remigial molt were Barrow's Goldeneyes (J. Thompson, personal observation).

Additional BTZ wetlands in Alberta that received use by ≥ 100 molting goldeneyes include George Lake, Majeau Lake, Powell Lake, Cutbank Lake, Bear Lake, Tawakwato Lake, Sandhill Lake, Winagami Lake, Ray Lake and Bush Lake (Fig. 1). While the productivity of these wetlands (i.e. eutrophic and hypereutrophic systems) suggests that they are likely more suitable molting sites for Barrow's than Common Goldeneyes (Eadie *et al.* 1995; Eadie *et al.* 2000), this has not been verified through ground surveys.

Satellite Telemetry

Of the 20 adult males marked with satellite transmitters at Riske Creek, six (30%) molted on Cardinal Lake and two of these birds molted there in consecutive years. The remaining

Table 1. Fixed-wing aerial survey counts of molting goldeneyes on Cardinal, Leddy, and Chip Lakes, AB 2004-2006. Estimates reflect the peak annual counts of goldeneyes at these sites over three molting surveys conducted each year. Concurrent ground surveys indicated ≥90% of goldeneyes on Cardinal and Leddy Lakes were Barrow's Goldeneyes (*Bucephala islandica*).

	Maximum Molting Goldeneye Counts		
Lake	2004	2005	2006
Cardinal	4,122	3,105	3,747
Leddy	286	568	96
Chip	613	2,178	1,564

14 males molted over a large area within the boreal forest east of the Rocky Mountains, extending from Lesser Slave Lake, Alberta to Great Bear Lake, North West Territories. Four of these males staged or stopped at Cardinal Lake on their way to or from other molting sites, two of which stopped at Cardinal Lake in consecutive years, indicating that half of the males marked at an intermountain breeding site used Cardinal Lake at some point in their annual cycle. Of the nine adult females marked at Riske Creek, none molted at either Cardinal or Leddy Lakes, however two molted at nearby sites within the BTZ. The remaining females molted near breeding sites in southwestern BC.

Of the three Indian Arm males marked with satellite transmitters, two birds molted on Cardinal Lake. One of five adult females marked at Indian Arm molted within the BTZ, east of Cardinal Lake. Three of the remaining females molted near breeding sites in southern BC, and one molted at a breeding site on the eastern slope of the Rocky Mountains.

Intensive Ground Surveys

Ground-based surveys conducted in 2009 during remigial molt provided maximum counts of 2,323 Barrow's Goldeneyes on Cardinal Lake and 1,855 on Leddy Lake. In 2010 a maximum of 6,060 and 730 Barrow's Goldeneyes were counted on these lakes, respectively. Peak fall staging counts of Barrow's Goldeneyes on Cardinal Lake were 1,224 and 5,238 in 2009 and 2010, respectively. Maximum fall staging counts on Leddy Lake were 820 and 220 in 2009 and 2010, respectively. Counts, particularly those from Cardinal Lake, should be treated as conservative estimates given that it is not possible to survey the entire lake from the ground, and ground surveys often provide low estimates of waterfowl abundance (Pagano and Arnold 2009a, 2009b).

Age/Sex Ratios

In 2009, we captured 277 and 305 Barrow's Goldeneyes on Cardinal and Leddy

Lakes, respectively. Adult (ASY) males accounted for 85% of the captured individuals on each lake. In 2010, we captured 464 and 182 birds on Cardinal and Leddy Lakes respectively, of which 78% of Cardinal birds and 83% of Leddy birds were ASY males. Adult males were the primary cohort undergoing remigial molt on these lakes (Table 2).

DISCUSSION

Identification of postbreeding sites for Barrow's Goldeneye in the BTZ of Alberta increases knowledge of this species' post-reproductive ecology. In particular, Cardinal, Leddy and Chip Lakes represent three of only five major molting areas known for Barrow's Goldeneyes in western North America. Surveys indicated numbers of molting Barrow's Goldeneyes of a similar magnitude to those at Old Crow Flats, Yukon Territory and Ohtig Lake, Alaska (King 1963; Van de Wetering 1997). Cardinal Lake is also the first known molting site for Barrow's Goldeneyes that breed in the intermountain region of British Columbia. Birds that breed and winter in BC could account for 60% of the world population of Barrow's Goldeneyes (Eadie *et al.* 2000). A high proportion of satellite marked, breeding males from Riske Creek, BC molted and/or staged at Cardinal Lake (50%), despite the presence of numerous alternative lake systems within the BTZ. Satellite telemetry indicated that some breeding females from Riske Creek also utilized the BTZ of Alberta for postbreeding activities. Chip and Leddy Lakes are also likely important molting sites for birds breeding in the interior of British Columbia. The long distances (>500 km) that these birds travelled in the opposite direction of their Pacific coast wintering regions suggests that these BTZ sites possess characteristics that are attractive to molting Barrow's Goldeneye, and that these may be relatively uncommon.

Characteristics of Cardinal, Leddy, and Chip Lakes are similar to those of previously known molting sites at Ohtig Lake and Old Crow Flats. All of these areas consist of large, shallow wetlands with abundant submergent vegetation. Each of these sites is also highly productive, supporting a large number of molting and fall staging waterfowl (King 1963; Van de Wetering and Cooke 2000). Similar molting habitat has been described for Barrow's Goldeneyes in northern Iceland at Lake Myvatn, although birds in this area also molted on a productive stretch of the Laxa River (Einarsson and Gardarsson 2004). Some males in eastern North America have been observed molting in coastal estuaries (Robert *et al.* 2002) however this behavior has not been observed for the western population. The similarity of water bodies used by molting Barrow's Goldeneyes suggests that birds are targeting a suite of specific habitat characteristics when choosing a molting location. While Cardinal, Leddy, and Chip Lakes appear to satisfy these preferences and represent sound foci for conservation efforts, further work should be undertaken to investigate other wetlands in the BTZ that supported significant numbers of molting goldeneyes (Fig. 1). Observed variability in survey counts of molting and staging birds between years suggests that individuals may not use the same location each year. Given that several males marked at Riske

Table 2. Proportion (%) of captured molting Barrow's Goldeneyes (*Bucephala islandica*) in each age and sex cohort on Cardinal Lake and Leddy Lake, AB in 2009 and 2010.

Year	Lake	Total Captured	Males (%)	Females (%)	Males SY (%)	Males ASY (%)	Females SY (%)	Females ASY (%)
2009	Cardinal	277	257 (93)	20 (7)	23 (9)	234 (91)	11* (58)	8* (42)
	Leddy	305	286 (94)	19 (6)	26 (9)	260 (91)	6 (32)	13 (68)
2010	Cardinal	464	417 (90)	47 (10)	55 (13)	362 (87)	20 (43)	27 (57)
	Leddy	182	162 (89)	20 (11)	10 (6)	152 (94)	7 (35)	13 (65)

*Percentages calculated from 19 females due to unknown age class of one individual.

Creek molted on other wetlands in the BTZ, it is likely that this landscape provides a number of suitable molting locations, and efforts should be made to locate and protect these sites.

The relatively small number of known molting sites for Barrow's Goldeneyes highlights the importance of conserving these sites. Many waterfowl species, Barrow's Goldeneye included, often remain at molting sites during fall staging, building energy reserves for migration to wintering habitats (Petersen *et al.* 2006; Savard *et al.* 2007; Savard *et al.* 2008). Data from Cardinal and Leddy Lakes indicate that Barrow's Goldeneyes are using these sites for up to five months. Similar patterns occur at molting sites in eastern Canada (Robert *et al.* 2002). Thus, quality of a molting/staging site may not only affect the quality of plumage grown, which affects thermoregulatory efficiency (Stettenheim 1976), but may also have cross-seasonal effects on individual fitness at subsequent stages of the annual cycle. Molting/staging habitat quality could indirectly affect reproductive success of Barrow's Goldeneyes six months later. Conserving these habitats may be particularly important considering the high rate of agricultural expansion within the BTZ (Mills 1994; Hobson *et al.* 2002) and the paucity of protected areas within this region.

Energy development is an additional threat in the BTZ that could directly affect postbreeding goldeneyes. Construction of large-scale nuclear power facilities in the region could result in fundamental changes to the ecology and hydrology of this system that would likely deter use of this site by postbreeding waterfowl. Currently, several sites in the vicinity of Cardinal and Leddy Lakes are under consideration for construction of western Canada's first nuclear power plant (Bruce Power 2009). Initial construction proposals considered the possibility of converting Cardinal Lake into a cooling pond for multiple nuclear reactors. Potential effects of this project or future developments proposed for this region should be carefully evaluated in advance of construction to understand their potential impacts to postbreeding Barrow's Goldeneye, one of the least abundant sea ducks in North America.

Given the potential importance of molting and fall staging habitat for waterfowl population dynamics, identification and protection of postbreeding sites should be a priority. Wetlands and shallow lakes in Alberta's BTZ, in particular Cardinal, Leddy, and Chip Lakes, provide molting and fall staging habitat for a significant proportion of the Pacific population of Barrow's Goldeneyes. To our knowledge, the aggregations described at these sites are among the highest densities of this species recorded in North America during any stage of the annual cycle. Discovery of these sites has provided the opportunity for more extensive research on the ecology of this species during the post-reproductive stages of the annual cycle. Ongoing work is focusing on understanding molting and fall staging phenology, survival and movements, as well as physiological and behavioral strategies employed during remigial molt and fall staging. These data will lead to a more complete understanding of how Barrow's Goldeneyes use postbreeding habitats, potentially lead to identification of other important molting sites in the BTZ and further aid development of conservation strategies for this species.

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