Tertial and Upper Wing Covert Molt in Young American Black Ducks

E. Paul Ashley[1], Scott A. Petrie[2], Norman R. North[3] and Robert C. Bailey[4]

[1]Canadian Wildlife Service, Ontario Region, RR 3 Port Rowan, ON. Canada N0E 1M0

[2]Long Point Waterfowl and Wetlands Research Fund, Bird Studies Canada,
P.O. Box 160, Port Rowan, ON. Canada N0E 1M0

[3]Canadian Wildlife Service, Ontario Region, 465 Gideon Drive,
P.O. Box 490 Lambeth Station, London, ON. Canada N6P 1R1

[4]University of Western Ontario, Department of Biology, London, ON. Canada N6A 5B8

Abstract.—American Black Ducks (*Anas rubripes*) molt some tertials and tertial coverts during their first fall and winter, but descriptions are incongruous and the timing, extent and sex-specific differences in molt patterns are largely unknown. We studied molt of these feathers from fall to spring using captive, harvested, and trapped wild birds, as well as specimen wings. During their first fall and winter, males molted earlier and replaced more tertials and tertial coverts than females, but all birds retained some juvenile tertial coverts until the end of April. We attribute these differences to their primary mating system of annual monogamy, with females being the limiting sex. The early acquisition of adult tertials and tertial coverts are likely selectively advantageous for males because these feathers are prominently displayed during courtship and pair bond formation. Young birds that have acquired adult-like feathers may exhibit a higher degree of fitness, facilitating breeding in the first year. This knowledge of wing feather replacement is useful for determining the age of Black Ducks as either *second year* or *after second year* and can also be used in dual feather isotope analysis to link natal and wintering areas. *Received 19 July 2006, accepted 31 March 2007.*

Key words.—after second year, American Black Duck, *Anas rubripes*, covert, molt, second year, tertial.

Waterbirds 30(3): 433-440, 2007

Descriptions of timing, extent, and sequence of American Black Duck (*Anas rubripes* hereafter Black Duck) wing molt prior to flight feather replacement in summer lack detail, and general descriptions differ. This is unfortunate given an understanding of temporal and spatial feather-replacement patterns is valuable for improving our knowledge of the molting process (Hohman *et al.* 1992; Pyle 2005) and useful for determining the age-classes of birds by identifiable characteristics of each feather generation (Ashley 2005). According to Palmer (1976), Black Ducks acquire juvenile plumage on the body and wing shortly after hatching followed by a partial body molt by late summer-early fall, although the occurrence of this molt was questioned by Pyle (2005). A molt of all body regions except the wing then occurs predominantly between September and November, considered the Prealternate 1 molt by Palmer (1976) and Preformative (formerly Prebasic 1 molt) by Pyle (2005). During this molt most of the juvenile wing is retained except for some tertials and tertial coverts. This plumage is worn throughout winter to summer for males, but only until late winter or spring for females, when the bird initiates another molt, considered part of the Definitive Prebasic molt by Palmer (1976) and the Prealternate 1 molt by Pyle (2005). The resulting body plumage provides cryptic coloration before nesting and the flightless period.

Palmer (1976) found that young Black Ducks replaced the innermost secondaries (also referred to as tertials) and *some* greater coverts during the first fall molt (hereafter termed the Preformative molt following Pyle 2005) while the remainder of the wing retained juvenile feathering until the spring (hereafter Alternate 1) molt. Juvenile tertials and tertial coverts are narrower and more rounded and worn than definitive tertials, allowing the separation of age groups (Carney 1992). However Carney (1992) indicated that the Preformative molt may be substantial, and stated that during the first fall and winter most Black Ducks replace their tertials and tertial coverts with adult-type feathers, making age determination more difficult. All Black Ducks aged by Ashley (2005) as being in their first year of life during winter/spring 2001 and 2002 retained at least one, and usually several juvenile tertial coverts, similar to Mallards (*Anas platyrhynchos*; Hopper and Funk 1970), but Ashley was unable to determine if some young birds had attained a complete set of tertial coverts and appeared to be older. The objectives of this study were therefore to determine the timing, extent and sequence of the Preformative wing covert and tertial molt, and to assess the reliability of age-determination criteria using these tracts.

METHODS

Study Area

The Long Point peninsula extends 35 km into the eastern basin of Lake Erie (80°30'E, 42°35'N to 80°03'E and 42°33'N) creating a 280,000 ha lacustrine embayment (Inner Bay) and 24,000 hectares of coastal wetlands. These wetlands are designated as a RAMSAR site (wetlands of international importance, especially for migratory waterfowl) and are some of the most significant staging areas for waterfowl in eastern North America (Dennis *et al.* 1984). Long Point generally supports 50,000 Black Duck use days in spring, 200,000 Black Duck use days in fall (Petrie 1998) and is at the northern edge of Black Duck wintering range, depending on ice conditions (Bellrose 1976; Ross 1987). All ducks captured in spring and most of those captured in fall were trapped at Big Creek National Wildlife Area (BCNWA), Long Point, Ontario, as they migrated between wintering grounds and northern boreal breeding grounds.

Feather and Age Nomenclature

Secondary flight feathers (attached to the ulna), are numbered beginning from the most distal (adjacent to primary 1) to the most proximal. For this study we considered the tertial group to consist of secondaries 11 to 14: the longest tertial, the next two proximal and the one distal to the longest tertial.

Covering the base of each remix (primaries, secondaries and tertials) on the upper side of the wing is a single row of greater coverts, comprised of primary, secondary and tertial coverts respectively. We counted greater upper secondary coverts beginning at the most distal feather and considered the tertial covert group to be the 13th to 17th greater upper secondary covert (tertial covert 1 to 5). Tertial coverts 1 and 2 (TC 1 and TC 2) are similar to greater upper secondary coverts in size and shape. TC 3 and TC 4 are larger and the most obvious feathers of this group, with TC 4 being the largest. TC 5 is much smaller, with size dependent upon feather generation.

We define ages of Black Ducks as young (a bird in its first summer, fall, winter or spring of life), or adult (a bird a least one year older than young birds). We determined age in fall and early winter using methods developed by Carney (1992) which assess condition, shape, and color of tertials, greater tertial coverts, middle and secondary lesser coverts and, greater primary coverts. Accuracy of age classification is reported to be ≥93%. For birds caught in spring we used methods developed by Ashley (2005) that assess condition, shape and color characteristics of primary coverts 4 to 7 and tertial covert 5 with a reported accuracy rate of ≥ 94%.

Data Sources

To meet the above objectives, we studied wings from: (1) three cohorts of first fall Black Ducks caught and held in captivity until the following spring; (2) Canadian Wildlife Service (CWS) Species Composition Survey (SCS); (3) hunter-harvested birds in southern Ontario, and; (4) free-ranging birds captured in fall and spring in southern Ontario.

Experimental Flocks

To monitor molt from December to April, we bait trapped, 89 young Black Ducks; 49 (32 male and 17 female) in 2001, 18 (twelve male and six female) in 2002 and 22 (14 male and eight female) in 2003. Birds were caught in late fall to decrease holding time and limit the impact of captivity on molt. Upon capture, we determined age (young, adult, or unknown) and sex by cloacal examination (Hochbaum 1942). One wing of each bird was photographed for reference and each bird banded with a U.S. Fish and Wildlife Service aluminum leg band for individual identification. We classified feathers from each feather group (primaries, secondaries, tertials and their associated coverts) as either adult or juvenile based on techniques developed by Carney (1992). To facilitate recognition of replaced feathers, we dyed the dorsal surface (excluding scapulars and post humerals) of one wing from each bird with a hydrogen peroxide based blonde hair dye (Goldwell topchic hair color 10-N, extra light blonde Goldwell Cosmetics (USA) Inc., Linthicum Heights, MD, 21090) between the last week of November and first week of December. We brushed the dye on one wing of each bird and wrapped the wing against the body with cotton cloth for 25 minutes to prevent exposure to the eyes or mouth while the dye set. The wing was then washed in warm, soapy water and rinsed.

Because environmental conditions such as light, temperature and diet are known to affect molt (Owen 1970; Richardson and Kaminski 1992; Barboza and Jorde 2001), we held the captive flock in as natural setting as possible. Birds were held in an outdoor pen (25 m long × 9 m wide × 3 m high) situated partially on land and partially in shallow water. Shelter, straw and fresh water were readily available. An aerator kept water from freezing during the winter. We fed a high quality diet of Duck Grower meal and mixed grains ad libitum at a 50:50 ratio. Crushed oyster shells were available for grit. It was important to assess molt under optimal nutritional conditions to provide an accurate approximation of the extent of molt that may be achieved in wild birds. For instance, if birds do not molt feathers under optimal nutritional conditions in captivity then it is unlikely that they would do so in the wild.

To assess the birds' ability to replace feathers in captivity, we pulled primary 5 (P 5), greater upper secondary coverts 5 and 9 (GUSC 5 and 9) and tertial covert 5 (TC 5) from the undyed wing at the time of dying in the 2003-2004 flock. Progression of molt for all flocks was quantified in mid December, mid February and the first week of April. In 2004, we monitored the birds until the first week of June. During each inspection, we examined wings for the presence of newly molted feathers. The number of replaced feathers in each feather group and their condition was also recorded. We conducted this research on the experimental flocks under Canadian Wildlife Service permit CA 0103.

Collection of Specimen Wings and Live Birds

To determine the timing, extent and sequence of wing molt from September to December, we analyzed wings from 255 young Black Ducks harvested in Ontario. In 2001 and 2002, we obtained 193 wings (N = 94 males, 99 = females) from the SCS and 58 wings (N = 27 males, N = 31 females) from harvested birds collected at the Long Point Waterfowl Management Unit and southern Ontario hunt clubs. We assigned age and sex to SCS wings using criteria developed by Carney (1992). All wings were re-examined by experienced CWS personnel and those that could not be positively identified (<5%) were discarded. The remaining sub-sample was considered to be "known-age" wings. Sex and age of wings from locally shot birds were determined by cloaca examination (Hochbaum 1942).

We captured Black Ducks during spring to verify that the extent of molt in captive birds was similar to that of wild birds. Thirty-nine young male and 16 young female Black Ducks were caught in March and April 2003 and 2004 using baited funnel traps at BCNWA. Birds were transported one km to a field station where they were held in pens containing straw and an ample supply of fresh water. Birds were typically held for approximately 24 hours to allow them to preen their feathers before analysis. Age was assigned by observation of feather characteristics developed by Ashley (2005) and we verified sex by the presence or absence of a penis (Hochbaum 1942).

Statistical Analyses

We pooled all specimens collected from September to December (SCS, specimens collected directly from hunters and captive birds) into sex/month cohorts. April birds consisted of two separate groups, captive birds and wild birds. Because wild birds were trapped at the end of March through to the second week of April we classified them as "April" specimens. To assess month (September, December and April) and sex-related (young male, young female) differences in number of feathers molted over the period of study we used a two-way ANOVA of square-root transformed count data. These tests yielded similar results as analyses using untransformed data, so we present here results from analyses using untransformed data. We used Fisher exact tests to determine whether the number of juvenile and adult tertials and tertial coverts were similar between captive and wild birds in spring (April captive birds vs. wild birds caught March/April). In all cases, null hypotheses were rejected with $P < 0.05$. Means are reported ± SD in text and tables.

RESULTS

Detection of Molt

Dyeing of wings allowed for easy recognition of molted feathers. New dark brown feathers contrasted with the pale light brown dyed feathers that had not been replaced (Fig. 1). Dyeing did not appear to affect molt since molt of undyed wings was similar to that of the dyed wings (Paul Ashley, pers. obs). During the study, there was no replacement of primaries, secondaries or associated coverts, except for some replacement of greater upper secondary coverts, median and lesser coverts attributed to adventitious replacement from handling.

Tertials

A 2-way ANOVA to assess the effect of sex and month (September, December and April) on number of juvenile tertials molted showed an interaction between these two variables ($F_{5.2, 2} = 286$; $P = 0.006$) (Fig. 2). Although not significant, ($P = 0.083$), males molted more tertials (22.0% of tertial observed) than females (8.1%) prior to collection in September. Males predominately molted juvenile tertials in September and October with most birds having a complete set of four adult tertials by December (92.0% of tertials observed). From December to April only 5.4% of captive males continued to molt tertials (0.1 ± 0.49 tertials replaced per bird) and by April just 4.0% of tertials observed on males were juvenile (Table 1). In contrast, only 43.3% of female tertials observed in December were adult. From December to April 39.0% of captive females

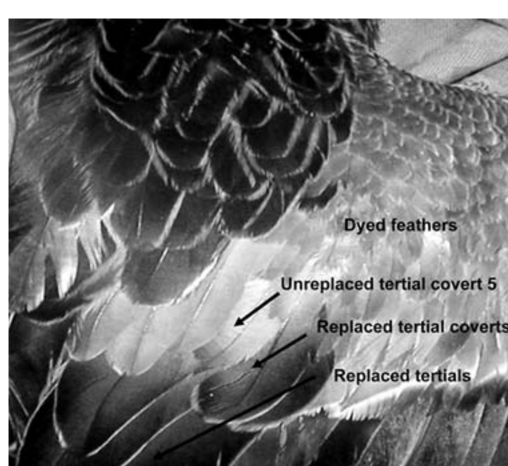

Figure 1. Dyed wing of a young American Black Duck (*Anas rubripes*) with replaced tertials and tertial coverts.

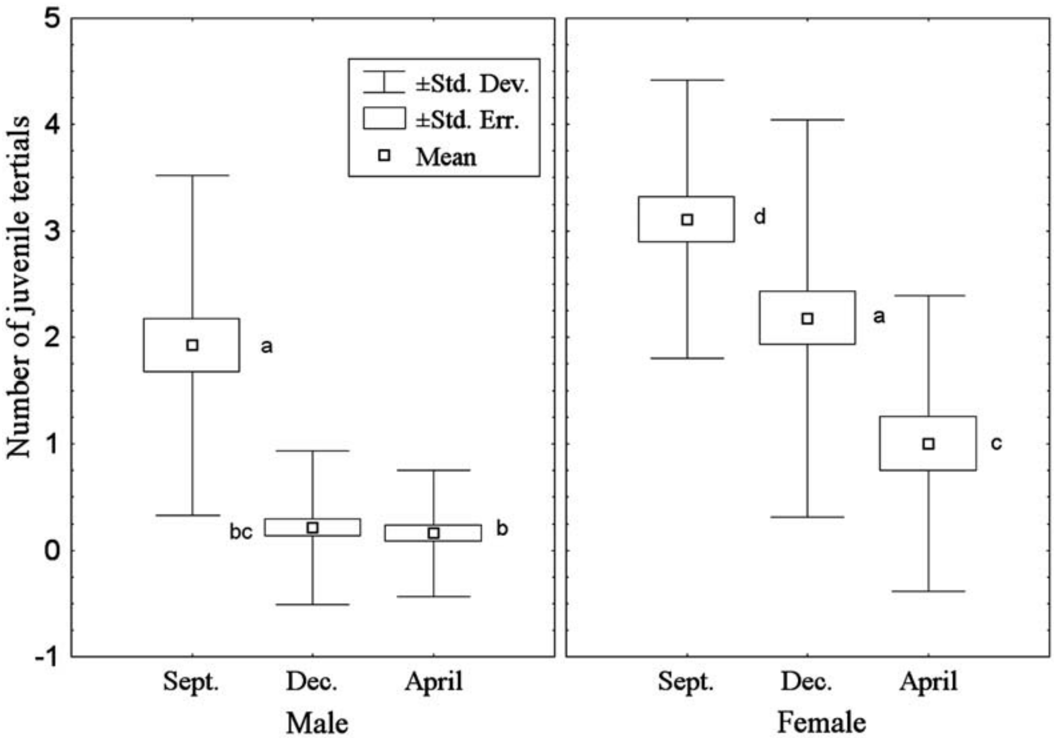

Figure 2. Number of tertials retained by young male and female American Black Ducks (*Anas rubripes*) in September (N = 39 male, N = 37 female), December (N = 78 male, N = 56 female) and April (N = 56 male, N = 30 female). Means with common postscripts are not significantly different (P > 0.05, Tukey HSD test).

continued to molt tertials (1.0 ± 1.4 tertials replaced per bird, P < 0.001), but by April 25.0% of tertials observed on captive females were still juvenile. Fewer males (7.1%) than females (46.7%) retained juvenile tertials into April. In 2004, five out of eight captive young females retained at least one juvenile tertial into June.

Feather replacement of captive and wild birds in April were similar (P > 0.05) except for female tertial 1 (T 1), where wild birds possessed more adult feathers (P = 0.013). There was a general pattern of replacing distal tertials earlier than proximal tertials, although this was quite variable.

Tertial Coverts

A 2-way ANOVA to determine the effect of sex and month (September, December and April) on the number of juvenile tertial coverts showed an interaction between month and sex ($F_{6.69, 2}$ = 296; P = 0.001) (Fig. 3). Nearly all birds possessed complete sets of juvenile tertial coverts in September with only a few adult feathers observed. Tertial covert molt was most active in fall for males and late winter/spring for females, although this was highly variable. Only 3.6% of males but 35.5% of females molted tertial coverts after December. From December to April, males essentially did not molt tertial coverts, (0.1 ± 0.55 tertial coverts replaced per bird) whereas females continued to do so (0.9 ± 1.33 tertial coverts replaced per bird, P < 0.001). This difference in winter molting rates resulted in captive males and females having a similar number of juvenile tertial coverts by April, 3.5 (± 1.57) and 3.2 (± 1.76) respectively. All males and all but one female retained at least one juvenile tertial covert when inspected in April. In 2004, the only year birds were kept until June, there was negligible molting of tertial coverts in both males (N = 14) and females (N = 8) between April and June. Only one female out of 89 young birds held in captivity replaced tertial covert 5 on the dyed wing.

An analysis of tertial covert replacement in wild and captive birds in April showed similar patterns for both males and females, the only exceptions being wild male TC 1 ($P = 0.010$) and TC 2 ($P = 0.011$) and wild female TC 1 ($P = 0.009$) and TC 2 ($P = 0.040$) which were more often adult. There was a general pattern of replacing distal tertial coverts earlier than proximal tertial coverts and TC 5 was never replaced during the study, with the exception of mechanical feather loss from handling.

Pulled Feathers

Feathers pulled in December were replaced by mid-February in all males (N = 14) and females (N = 8). Greater upper secondary coverts and tertial coverts were completely grown and primary 5 was generally 80% grown. Primary 5 was fully grown by the first week of April. Replaced greater upper secondary coverts were darker, slightly larger but similar to antecedent juvenile feathers in shape. Replaced tertial coverts were darker than antecedent juvenile feathers and exhibited adult-like characteristics (unfrayed, not faded, large with rounded to broadly rounded tips).

DISCUSSION

The only wing feathers to molt systematically from fall to spring were the tertials and tertial coverts, and no substantial replacement of other wing feathers was observed. Some replacement of coverts (usually median coverts) during winter on a few of the captive birds was observed. This appears to be a characteristic of Preformative molt in the group *Anas* (Peter Pyle 2006, pers. comm.). Because feathers plucked in December were rapidly replaced, conditions of captivity appear not to have limited the ability of Black Ducks to molt in winter. On the contrary, molt of captive birds appeared to be at least on par with wild birds. Exceptions included some distal tertials and tertial coverts, which may have been misidentified because of the similarities between feather generations. Dif-

Table 1. Percent and mean number of young male, N = 56 and female N = 31, American Black Ducks that molted tertials, tertial coverts (TC), greater upper secondary coverts (GUSC), and primary coverts (PC) from December to April.

Feather group	# of feathers	% of birds that molted feathers (December to April)		% of birds retaining juvenile feathers in April		% juvenile feathers[a] in April		Mean number of juvenile feathers[b] (± SD) (December to April)			Mean number of molted feathers[c] (± SD) (December to April)		
		male	female	male	female	male	female	male	female	P	male	female	P
Tertial	4	5.4	40.0	7.1	46.7	4.0	25.0	0.2 (0.60)	1.00 (1.39)	0.002	0.1 (0.49)	1.0 (1.40)	<0.001
TC	5	3.6	36.7	100.0	96.7	67.9	63.3	3.5 (1.57)	3.20 (1.76)	NS	0.1 (0.55)	0.9 (1.33)	<0.001
GUSC	12	0.0	3.2	100.0	99.7	100.0	100.0	12.0 (0.00)	11.97 (0.18)	NS	0.0 (0.00)	0.0 (0.18)	NS
PC	9	0.0	0.0	100.0	100.0	100.0	100.0	9.0 (0.00)	9.00 (0.00)	NS	0.0 (0.00)	0.0 (0.00)	NS

[a]Number of juvenile feathers observed/number of feathers in group × 100.
[b]Mean number of juvenile feathers observed per bird.
[c]Mean number of feathers replaced per individual between December and April.

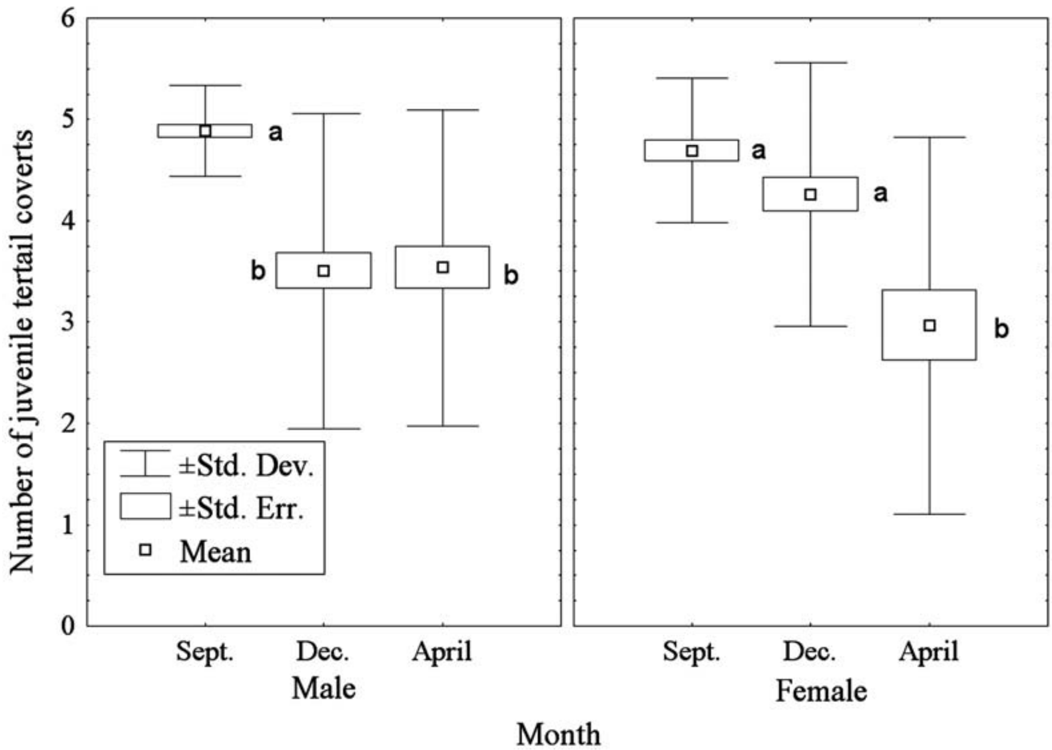

Figure 3. Number of tertial coverts retained by young male and female American Black Ducks (*Anas rubripes*) in September (N = 44 male, N = 42 female), December (N = 79 male, N = 58 female) and April (N = 56 male, N = 30 female). Means with common postscripts are not significantly different (P > 0.05, Tukey HSD test).

ferences in age classification of these feathers are attributed to the difficulty of assigning ages based on qualitative characteristics of wear and shape.

Most Black Ducks retained a complete set of juvenile tertial coverts in mid-September and did not initiate tertial covert molt until after tertial molt had begun. Sex-related differences in patterns of tertial covert molt from September to April were similar to those of tertials. Males molted tertial coverts throughout fall and by December had four or less adult tertial coverts. Molt on the wing was negligible during winter, a pattern similar to that of Mallards (Hopper and Funk 1970) and Northern Pintails (*Anas acuta*) (Smith and Sheeley 1993). The apparent discrepancy between Palmer's (1976) assertion that some innermost greater coverts molt, and Carney's (1992) claim that a substantial fraction of young birds replace their tertial coverts (*viz. all*) during winter may possibly be attributed to their definition of tertial coverts. For Carney's purposes, (i.e., determining age-class through plumage) the largest and most easily recognizable tertial coverts often do molt while those positioned antecedent and subsequent to them often do not.

Sex-related differences in the timing of molt in Anatinae are most evident with the onset of Alternate plumage, and are indicative of sex-specific strategies of reproduction and associated time and energy constraints (Hohman *et al.* 1992). However, sex-related differences in timing and extent of tertial molt most likely begin prior to September at the onset on Preformative molt (as indicated by marginal sex-specific differences in feather generation as early as the September collection date) and may be attributed to sex-specific courtship displays and pair bond formation which begins in early autumn. Black Ducks mainly employ a mating strategy of annual monogamy (Johnsgard 1960) but due to nesting ground mortality of females there is a male biased sex ratio. Consequently, females are the limiting sex and there is competition among males for females, and females are able to be selective when choosing mates. Courtship behavior of Black Ducks involves an elaborate ritual of head and tail bobbing, nod swimming, flights, calling and displaying of plumage (Trautman 1947), including prominent use of the wing coverts and tertials in males (Johnsgard 1960). Thus, the early acquisition of larger and more prominent tertials and tertial coverts may be more advantageous for the procurement of mates for males than females (McKinney 1970).

It appears that once Preformative molt of body regions ceases, molt on the wing also ceases until Prealternate 1 molt. Some females replaced tertial coverts during winter, which is common among several genera of Anatinae, including Wood Ducks (*Aix sponsa*, Harvey *et al.* 1989), Canvasbacks (*Aythya valisineria*, Haramis *et al.* 1982) and Mallards (Hopper and Funk 1970). In females, feathers in the tertial and tertial covert group molt concurrently with Preformative molt, and continue to be replaced with the Prealternate 1 molt. Because Preformative molt is initiated later in females and Prealternate 1 is initiated earlier, there appears to be molting throughout winter with no discrete break, as observed in males. Individual birds may cease molting for a short period between these molts (Hohman *et al.* 1992) but winter molt may be more satisfactorily viewed in females as a continuum from one molt into another.

The timing and extent of tertial and tertial covert molt does not appear to be controlled by the replacement of specific feathers or feather groups. That is, birds do not necessarily continue to molt until all feathers within a specified tract have molted. Rather, proximate factors such as age, nutrition, pair status and environmental conditions (Heitmeyer 1987; Leafloor and Ankney 1991) regulate endocrine control of molt (Bluhm 1988). Because of this, there is much variability and overlap in molt schedules between individuals and populations. Thus, it is possible to find Black Ducks in the same wintering area in different molts, e.g. one completing Preformative molt at the same time another initiating Prealternate 1 molt (Heitmeyer 1987).

Knowledge of wing molt will be useful for future research, conservation and management of Black Ducks. Despite individual and sex-related variation in the extent of molt, tertial covert molt was limited to only the first four coverts, with TC 5 always retained throughout winter and spring. This makes TC 5 a useful feather for determining age classes of Black Ducks to early summer because of obvious differences in size, shape and wear between feather generations. The ability to determine age classes of Black Ducks from late winter to early summer will facilitate aspects of Black Duck research requiring age-specific data, such as productivity and age-specific survival rates. Also, knowledge of tertial covert molt may be useful for the conservation of the species by linking natal origins with wintering areas and staging areas through dual feather stable isotope analysis. For example, young Black Ducks caught on spring staging areas possess feathers grown on natal areas (e.g., primaries and secondaries) and feathers grown on wintering areas (tertial coverts 3 and 4 if replaced). Analysis of these feathers collected during a large-scale monitoring study could establish relative contributions of wintering populations to breeding populations and may provide insight into the disparate population trends observed in the Atlantic and Mississippi Flyways.

ACKOWLEDGMENTS

We thank M. Brock, D. Bernard, J. Vanos, J. Haggeman, M. Wernaart, and J. Reaume for field assistance and K. Brown cared for the captive flocks. R. Scott, J. Millar, provided helpful comments on the manuscript. P. Pyle also provided many insights into waterfowl molt. Financial support was provided by the Long Point Waterfowl and Wetlands Research Fund through funding by the Bluff's Hunt Club, Canadian Wildlife Service, Environment Canada and the Ontario Federation of Anglers and Hunters (Simcoe Chapter).

LITERATURE CITED

Ashley, E. P. 2005. Wing moult and age determination of American black ducks (*Anas rubripes*). MSc. thesis. Department of Biology, University of Western Ontario, London, Ontario.

Barboza, P. S. and D. G. Jorde. 2001. Intermittent fasting during winter and spring affects body composition and reproduction of a migratory duck. Journal of Comparative Physiology 172: 419-434.

Bellrose, F. C. 1976. Ducks, Geese and Swans of North America 2nd ed. Stackpole Books, Harrisburg, PA.

Bluhm, C. K. 1988. Temporal patterns of pair formation and reproduction in annual cycles and associated endocrinology in waterfowl. Current Ornithology 5: 123-185.

Carney, S. M. 1992. Species, age and sex identification of ducks using wing plumage. U.S. Department of Interior. U.S. Fish and Wildlife Service, Washington, D.C.

Dennis, D. G., G. B. McCullough, N. R. North and R. K. Ross. 1984. An updated assessment of migrant waterfowl use of Ontario shorelines of southern Great Lakes. Pages 37-42 *in* Waterfowl Studies in Ontario (S. G. Curtis, D. G. Dennis and H. Boyd, Eds.). Canadian Wildlife Service Occasional Paper No. 54.

Haramis, G. M., E. L. Derleth and D. G. McAuley. 1982. Techniques for trapping, aging, and banding wintering canvasbacks. Journal of Field Ornithology 53: 342-351.

Harvey, W. F., G. R. Hepp and R. A. Kennamer. 1989. Age determination of female wood ducks during the breeding season. Wildlife Society Bulletin 17: 254-258.

Heitmeyer, M. E. 1987. The prebasic moult and basic plumage of female mallards (*Anas platyrhynchos*). Canadian Journal of Zoology 65: 2248-2261.

Hochbaum, H. A. 1942. Sex and age determination of waterfowl by cloacal examination. Transactions of North American Wildlife Conference 7: 299-307.

Hohman, W. L., C. D. Ankney and D. H. Gordon. 1992. Ecology and management of postbreeding waterfowl. Pages 128-189 *in* Ecology and management of breeding waterfowl (B. D. J. Batt, A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec and G.L. Krapu, Eds.). University of Minnesota Press, Minneapolis.

Hopper, R. M. and H. D.Funk. 1970. Reliability of mallard wing age determination technique for field use. Journal of Wildlife Management 34: 333-339.

Johnsgard, P. A. 1960. A quantitative study of sexual behaviour of mallards and black ducks. Wilson Bulletin 72: 133-155.

Leafloor, J. O. and C. D. Ankney. 1991. Factors affecting wing molt chronology of female mallards. Canadian Journal of Zoology 69: 924-928.

McKinney, F. 1970. Displays of four species of blue-winged ducks. Living Bird 9: 29-64.

Owen, R. B. 1970. The bioenergetics of captive blue-winged teal under controlled and outdoor conditions. Condor 72: 153-163.

Palmer, R. S. 1976. Handbook of North American birds, Vol. II. Yale University Press, New Haven, CT.

Petrie, S. A. 1998. Waterfowl and Wetlands of Long Point Bay and Old Norfolk County: Present Conditions and Future Options for Conservation. Unpublished Norfolk Land Stewardship Council Report. Long Point Waterfowl and Wetlands Research Fund, Port Rowan Ontario.

Pyle, P. 2005. Molts and plumages of ducks (Anatinae). Waterbirds 28: 208-219.

Richardson, D. M. and R. M. Kaminski. 1992. Diet restriction diet quality and prebasic moult in female mallards. Journal of Wildlife Management 56: 531-539.

Ross, R. K. 1987. Interim report on waterfowl breeding pair surveys in Northern Ontario, 1980-1983. Canadian Wildlife Service Progress Note 168.

Smith, L. M. and D. G. Sheeley. 1993. Moult pattern of wintering northern pintails in the southern high plains. Journal of Wildlife Management 57: 229-238.

Trautman, M. 1947. The courting behavior of the Black Duck. Wilson Bulletin 59: 26-35.