Plumage Characteristics as an Indicator of Age Class in the Surf Scoter

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Abstract.—We assessed reliability of plumage as an indicator of age class in the Surf Scoter (*Melanitta perspicillata*) for demographic and behavioral studies. Three age classes were distinguished among male Surf Scoters, based on the degree of concordance between plumage characteristics and known age-related features (bursal depth and tail feather notching). Males in their first year (1Y) were distinguishable from older males (>1Y) with nearly total accuracy. Discriminating between second year (2Y) and after second year (>2Y) males had an error rate of 11%. Female Surf Scoters could not be reliably aged using plumage characteristics. Field observations suggested the timing of feather changes is an important variable affecting accurate age class determination. First year male Surf Scoter plumage is brown and female-like at the time of fledging, and gradually becomes more adult male-like during the first year. Observations of plumage changes throughout the annual cycle on wild birds suggested that females and 1Y males may be confused in early autumn, and that 1Y males and 2Y males may be misidentified during late spring and summer. Further, variation in timing and speed of pre- and post-breeding molt among 2Y and older males is uncertain. Therefore, mid-January until the end of March is the period when age class determinations based on plumage are most reliable. *Received 5 June 2002, accepted 10 October 2002.*

Key words.—Age determination, bursal evaluation, Melanitta perspicillata, plumage appearance, sea duck, Surf Scoter, tail feather notching.

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Determining age classes of animals is important for assessing productivity and recruitment patterns, estimating age-specific survival and reproduction, and investigating life history characteristics. Plumage traits have proven useful for differentiating age classes in a wide range of avian taxa for evolutionary and ecological studies (Lyon and Montgomerie 1986; Cowardin and Blohm 1992; Chu 1994). Techniques that allow age class separation on the basis of plumage appearance are particularly important for groups such as sea ducks, where individuals are difficult to capture or obtain as carcasses (Duncan and Marquiss 1993; Smith *et al.* 1998).

Sea duck numbers have shown long term declines and recent attention has focused on identifying the causes of these declines (U.S. Fish and Wildlife Service 1993; Goudie *et al.* 1994). For the Surf Scoter (*Melanitta perspicillata*), detailed demographic data are needed to ascertain both the mechanisms underlying population changes and the life stages at which they are occurring. The ability to differentiate age classes is fundamental to this endeavor. Variation in Surf Scoter plumage has been described and assumed to be related to age (Palmer 1976; Bellrose 1980), although the accuracy and reliability of age class determinations by plumage characteristics have never been quantified. Further, the timing and duration of transitional stages between juvenal (defined as a the first covering of true contour feathers—see Humphrey and Parkes 1959) and adult plumages have never been described. The objective of this study was to evaluate the usefulness of plumage as an age class indicator for the Surf Scoter in ecological research. To this end we addressed three questions:

1) How many age classes are identifiable by plumage for each sex?
2) Do age class designations based on plumage characteristics concur with assignments made by evaluation of bursal depth and the presence or absence of notched tail feathers?
3) Which plumage traits are most useful for distinguishing sex and age classes, and at what stage in the annual cycle are these determinations most reliable.

METHODS

Assessing plumage as an indicator of age class

During November 2000-April 2001, 87 Surf Scoters were captured in the Strait of Georgia, British Columbia, Canada, using a floating mist technique modified from Kaiser *et al.* (1995) and Rosenberg and Petrula (1998). Captured birds were scored for pattern and coloration on eight plumage and morphological traits (Table 1). A cumulative plumage score was then calculated and used to assign individuals to putative age classes. Surf Scoter broods hatch in mid to late July (Savard *et al.* 1998), and it is assumed that sexual maturity is not reached for two or more years (Livezey 1995). To avoid any a prior assumptions about the relationship between plumage stage and age, three hypothetical age classes corresponding to the annual cycle were considered: first year (0-12 months) (1Y), second year (13-24 months) (2Y), and after second year (>24 months) (>2Y).

Hatchling (see Lesage *et al.* 1997) and definitive alternate adult (see Palmer 1976) plumages have been described in detail for the Surf Scoter, and were used to develop the hypothetical age class criteria. Each trait matching the breeding adult male condition was scored as 3 and those matching the condition displayed at the time of fledging as 0 (Table 1). Transitional stages were scored according to their degree of similarity to maximum or minimum values. For males, individuals scoring the maximum value on all eight traits, score = 24, were tentatively classified as >2Y. Individuals with incomplete ornamental traits—small forecrown or nape patches and/or less bill coloration, but otherwise definitive adult plumage scored 15-23, and were classified as 2Y, while those with both reduced ornamental and fledgling-like non-ornamental traits scored < 15, and were classified as 1Y. For females, the same scoring criteria were used. Less plumage variation was evident among females, therefore, only two putative age classes were considered—immature and >2Y, where immature is used as a collective assignment that includes both 1Y and 2Y birds. Immature females, with scores ≤4, were predicted to differ from >2Y females, with scores > 4, by the absence of a nape patch, lighter breast and belly coloration, and larger white cheek spots.

During December 2001, we used an additional sample of 42 Surf Scoters, captured at another location within the Strait of Georgia, to assess whether our age assignments were reliable and repeatable among sites and between years.

In the absence of known age specimens, bursal depth and the presence or absence of tail feather notching was used to evaluate the likelihood that our putative age class determinations were correct. The bursa of Fabricius is an immunosuppressive organ that forms as a sac on the dorsal surface of the cloaca in birds (Glick 1983). Evaluation of bursal depth has been successfully used to determine age class in numerous waterfowl field studies (e.g., Ankney and Alisauskas 1991; Esler and Grand 1994; Hohman *et al.* 1995). For sea ducks, which do not breed for two or more seasons following hatching, the degree of bursal involution has been shown to be an accurate measure of age (Peterson and Ellarson 1978; Mather and Esler 1999). Bursal depth was measured (±1 mm) by inserting a metal probe into the exposed bursal sac. To limit potential measurement errors, only the authors probed bursae. Using findings of Mather and Esler (1999) for the Harlequin Duck (*Histrionicus histrionicus*), Surf Scoters with bursal depths (10 mm were recorded as >2Y and those with bursal depths ≥10 mm as immature. The presence or absence of notched tail feathers (Carney 1992) was noted in the December 2001 sample and used to distinguish 1Y from 2Y birds. Notched tail feathers are present only in 1Y birds. They result from the loss of downy feathers when the tail feather emerges from its follicle and remain evident through the first winter of the annual cycle.

Using both bursal and tail feather examination, we established the following criteria for assigning captured Surf Scoters to age classes: >2Y—shallow bursas (≤10 mm) and un-notched tail feathers; 2Y—deep bursas (>10 mm) and un-notched tail feathers; and 1Y—deep bursas and notched tail feathers. Concordance between plumage and bursal depth/tail feather age determinations was assessed from contingency tables, using Fisher's exact test to determine whether plumage scores were independent of bursal depth and tail feather notching criteria.

Optimal survey timing and post-juvenal feather replacement

At 3-5 week intervals, between October 2000 and August 2001, observational molt data were collected on 620 wild Surf Scoters to investigate the extent and timing of different plumage stages. During each sample session, plumage scores were recorded for up to 15 representatives from each provisional age class. Focal individuals were selected at random from flocks <100 m from shore, using a 20-60x spotting scope. Only six of

Table 1. Score system for traits used to estimate age class using plumage appearance for male and female Surf Scoters.

	Score				
Trait	0	1	1.5	2	3
Bill coloration	Brown	Outline of adult		Dull adult	Fully developed
Breast and belly	Light tan	Brown		Mottled	Black
Crown feathers	Brown		Mottled		Black
White forecrown patch	Absent	Faint strands		Incomplete	Complete
Iris color	Brown		Yellowish		White
Cheek spot size	>50% face		<50% face		Absent
White nape patch	Absent	Faint strands		Incomplete	Complete
Upper wing coverts	Brown		Mottled		Black

the eight traits (nape patch, bill, crown, cheek, forecrown patch, and upper wing coverts) could be consistently inspected, due to difficulties assessing breast and belly coloration and iris coloration among the wild birds on the water. Multivariate analysis indicated that all eight traits were highly correlated among captured birds. Therefore, we used a reduced plumage score model (hereafter "$score_{reduced}$"), containing the six easily observed traits, when analyzing plumage changes among wild birds.

Molt sequence and the duration over which individual trait conditions persisted were quantified by estimating the relative frequency of trait condition scores by month, for each class. Linear regression of plumage $score_{reduced}$ against date was performed to identify intervals over which the sexes and age classes displayed unique plumages. Optimal times for surveys were defined as those in which the overlap of 95% prediction intervals for plumage scores was minimized.

RESULTS

Reliability of plumage as an indicator of age

Age classes determined by plumage score yielded concordant results with those determined using bursal depth for 61 of 67 male Surf Scoters captured during November-April 2000-01 (Table 2; Fisher's exact test, $P < 0.001$). Among the six males showing discrepancies, four exhibited incomplete white forecrown patches (scores = 22-23), but otherwise definitive alternate male plumage and bursal depths ≤10 mm and the remaining two exhibited definitive alternate male plumage (score = 24) and bursal depths > 10 mm. Among the males classified as immature by bursal depth, eleven exhibited reduced ornamental traits and had fledgling-like non-ornamental traits (scores < 15). The plumage of these males was highly distinctive and they were presumed to be 1Y males.

The December 2001 sample corroborated these results (Fig. 1). The age determination techniques agreed for 29 of 32 males, with the three discrepancies occurring in a similar proportion to the first sample (Table 2; Fisher's exact test, $P < 0.001$). All eight males with score < 15 had notched tail feathers, whereas, the 24 males with score ≥15 had tail feathers that were not notched. Classification errors (±SE) between 2Y and >2Y males occurred in 13% (±7%) (N = 24) of the December 2001 sample, and 11% (±4%) (N = 80) of the two samples combined.

Female Surf Scoters could not be reliably classified into age groups on the basis of plumage score (Table 2). The error rate was 30% (±11%) for November-April 2000-01 (N = 20), and 30% (±16%) for December 2001 (N = 10). These classification errors all involved females aged as >2Y by bursal depth (≤10 mm), and which exhibited lightly colored breast and belly plumage.

Optimal survey timing and post-juvenal feather replacement

We describe the timing of post-juvenal feather replacement for birds observed in the wild only for male Surf Scoters, because females were not reliably distinguished by plumage. Cumulative plumage score, $score_{reduced}$ (±SE), increased with date for 1Y males: $score_{reduced} = 1.73 (\pm 0.51) + 0.90 (\pm 0.06) * date$, ($F_{1,200} = 227$, $P < 0.001$, $r^2 = 0.53$, N = 202), but remained constant for 2Y

Table 2. Concordance between age class assignments determined by plumage score and bursal depth evaluation for Surf Scoters captured in the Strait of Georgia, British Columbia, November-April 2000-2001 and December 2001.

		Male		Female	
Plumage score age	Bursal depth age	Nov 00-Apr 01 (N = 67)	Dec 01 (N = 32)	Nov 00-Apr 01 (N = 20)	Dec 01 (N = 10)
>2Y	>2Y	72%	41%	55%	30%
Immature	Immature	19%	50%	15%	40%
Immature	>2Y	6%	6%	30%	30%
>2Y	Immature	3%	3%	0%	0%
Probability techniques not independent (Fisher's exact test)		P < 0.001	P < 0.001	n.s.	n.s.

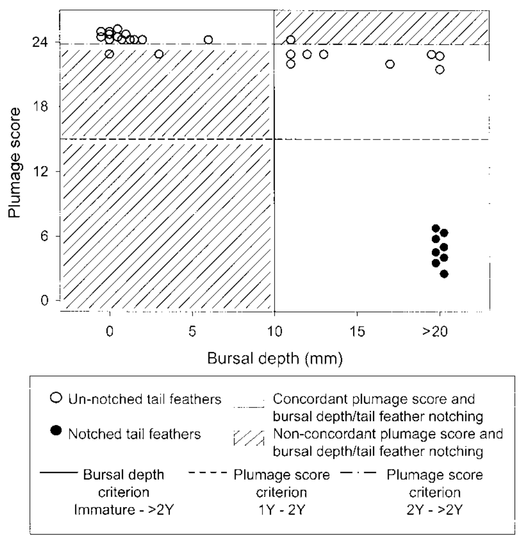

Figure 1. Concordance between age class determinations made using plumage score compared to bursal depth and tail feather notching criteria, for male Surf Scoters captured in the Strait of Georgia (N = 32), British Columbia, Canada, during December 2001.

males ($F_{1,31}$ = 0.66, n.s, r^2 = 0.02, N = 33), >2Y males (by definition, N = 186), and for females ($F_{1,198}$ = 0.02, n.s., r^2 < 0.01, N = 199) (Fig. 2). The proportion of 1Y males with plumage score prediction intervals that did not overlap with scores of 2Y males, >2Y males or females increased from autumn to late-winter, as 1Y males differentiated from females (Oct/Nov 6%, N = 32; Dec/Jan 90%, N = 51; Feb/Mar 98%, N = 49). The proportion then decreased in spring and summer as 1Y males became more adult male-like (Apr/May 93%, N = 43; Jun-Aug 85%, N = 26).

All six plumage traits used to evaluate wild Surf Scoters contributed to separating 1Y males from 2Y males, >2Y males, and females. During autumn, 1Y males closely resembled females. They were characterized by the absence of white nape and forecrown patches, had white spots covering >50% of the cheek, and exhibited brown crown feathers and upper wing coverts (N = 32). Bill coloration was useful for separating 1Y males from females during autumn, as 1Y males gradually attained multi-colored adult male-like bills. Most 1Y males developed partial white nape patches by the end of February (79%, N = 45), however forecrown patches remained absent. Black feathering on the crown and disappearance of white cheek spots was evident in over half of 1Y males in December and January (N = 32). By February, more than 95% of 1Y males exhibited the black crown and face feathering characteristic of older males (N = 45). Upper wing coverts began to be mottled with black feathers in January. However variability was high, and entirely brown upper wing coverts were evident in 1Y males until mid-February (42% N = 45).

1Y males increasingly resembled 2Y and >2Y males in spring. During April-June (N = 43), most 1Y males exhibited at least partial white nape patches (86%), and small white forecrown patches began to appear in some birds (30%), however their bills continued to lack the vibrant coloration of older males. The face and crown of 1Y males was entirely black by spring, and upper wing coverts remained mottled brown and black (79%). Fully adult-like bills and black upper wing coverts were first evident among the cohort in August, at the onset of the second annual cycle (N = 26).

Breast and belly feathering could not be scored on all birds seen in the field. However, among the 1Y males for which it could be

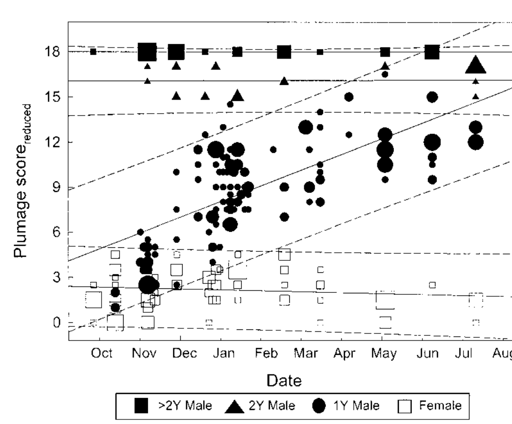

Figure 2. Seasonal change in Surf Scoter plumage scores, October 2000-August 2001. Age class assignments made according to plumage on wild birds observed in the Strait of Georgia. Solid lines represent regression of plumage score against date; dashed lines indicate 95% prediction intervals. Sizes of symbols are proportional to the number of individuals in sample with identical plumage scores. Maximum score = 18.

observed (N = 121), it was useful. All 1Y males exhibited light tan feathering, which contrasted sharply with darker body feathers from October through the end of their first annual cycle. Light tan belly feathers were also replaced with black ones during the July/August body molt.

2Y male Surf Scoters were characterized by incomplete or absent white forecrown patches, but otherwise showed adult plumage during winter. The observations on wild Surf Scoters were too infrequent to ascertain the precise timing of 2Y male forecrown patch, nape patch, and bill coloration development. Nape and forecrown patches appeared to be lost in at least a portion of all three male age classes in late summer/early autumn (Jul-Oct, N = 72). Differentiation of 2Y and >2Y males was not considered possible at that time of year owing the uncertainty of timing and speed of molt in these two age classes (see Robertson *et al.* 1998).

DISCUSSION

Our results confirm that ages of male Surf Scoters can be reliably determined by plumage. We found that three distinct plumage stages corresponding to 1Y, 2Y, and >2Y in the annual cycle were discernible among males, and these stages were concordant with age class determinations using bursal evaluation and tail feather examination. Plumage appearance, however, could not be used to accurately determine age class in female Surf Scoters.

The time of year was an important consideration for accurate age class estimation. During autumn, 1Y males shared several plumage characteristics with females and by late spring they closely resembled 2Y males. From mid-January until the end of March, 1Y male Surf Scoters were most clearly identifiable. During this time, they exhibited dull multi-colored orange, white, and black bills, partially developed white nape patches, markedly light breast and belly feathering, mottled black and brown upper wing primary coverts, and lacked both white forecrown patches and cheek spots. Using a two-age classes model for males, 1Y birds could be distinguished from >1Y birds with total accuracy.

2Y male Surf Scoters could be identified at close range by their black belly plumage and reduced or absent forecrown patches. We estimated an error rate of 11% when separating between 2Y and >2Y males in our winter captures. However, this error rate is likely to be higher in autumn, if slow molting >2Y males are confused with 2Y males, and in the spring, if some 2Y males acquire forecrown patches early. In addition, our error rate includes measurement error, as observers may misclassify plumage traits and bursae may be damaged when probed (Hanson 1949). Similar error rates have been reported in other waterfowl age determination studies, using a variety of techniques, including wing characteristic-bursal evaluation comparison—5-19% Northern Shoveler (*Anas clypeata*), 14-32% Blue-winged Teal (*A. discors*), 25-32% Cinnamon Teal (*A. cyanoptera*) (Hohman *et al.* 1995), wing characteristics of known age samples—7% female American Wigeon (*A. americana*) (Wishart 1981) and 13% Northern Pintail (*A. acuta*) (Duncan 1985), and bursal evaluation of recaptured birds—10% Harlequin Ducks (Mather and Esler 1999).

The ability to accurately identify age classes in the Surf Scoter improves the ability to estimate crucial demographic parameters and make inferences about the mechanisms underlying population change. There are currently very few detailed studies of population processes and dynamics in scoters (see Krementz *et al.* 1997) and none that include demographic data from wintering areas. Use of plumage characteristics to sample age-specific flock composition patterns and quantify between year fluctuations in adult to young ratios would be a useful tool for monitoring sea duck productivity and recruitment (Iverson 2002; Smith *et al.* 2001). Similar approaches to assessing plumage characteristics as an indicator of age are likely to be successful in other sea duck species, where such information is vitally needed. It is hoped that by collecting age-specific demographic and behavioral data on a number of species, we will be better equipped to manage sea duck populations.

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