

## AGE AND SEX DISTRIBUTIONS OF WINTERING SURF SCOTERS: IMPLICATIONS FOR THE USE OF AGE RATIOS AS AN INDEX OF RECRUITMENT

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**Abstract.** We assessed age- and sex-specific distribution patterns of Surf Scoters (*Melanitta perspicillata*) wintering in southern coastal British Columbia, Canada, and evaluated potential biases associated with the use of male age ratios as an index of their recruitment. For surveys conducted during 2000 through 2002, annual variations in male age ratios were evident, with estimates ranging from 0.07  $\pm$  0.02 to 0.13  $\pm$  0.03 (SE; first-year males:total males). Flock composition patterns indicated first-year males did not distribute independently, but tended to associate with other first-year males. With respect to habitat, male age-class proportions did not vary among shoreline substrate types, but higher proportions of first-year males were found in sites with low exposure to wind and waves (< 50 km fetch). To determine the efficacy of male age ratios for indexing recruitment, we used a power analysis, which incorporated overdispersion in age-class segregation and determined the sample sizes required for precise estimates of the proportion of first-year male Surf Scoters. Samples of approximately 600–1000 total males were required to obtain 95% confidence limits within 5% of the estimated mean, with sampling accuracy leveling off at about 2% when 6000 or more males were aged. Recruitment among waterfowl species is typically modeled using the ratio of female recruits to breeding-age females. Based on the sex and male age-ratio estimates obtained in this study, we calculated a female age ratio of 0.23 (first-year females:adult females).

**Key words:** age-ratio estimation, flock, *Melanitta perspicillata*, overdispersion, recruitment, seaduck, Surf Scoter.

Distribuciones Invernales de Edad y Sexo en *Melanitta perspicillata*: Implicancias del Uso de Cocientes de Edad como un I

típicamente usando el cociente entre nuevas hembras y hembras en edad reproductiva. Basados en las estimaciones de cocientes de sexo y edad de los machos obtenidas en este estudio, calculamos un cociente de edad de las hembras de 0.23 (hembras del primer año: hembras adultas).

## INTRODUCTION

Few reliable population indices or estimates of annual productivity are available for seaducks (Anatidae: Mergini) in North America. Analyses of existing survey data indicate declining population trends among 10 of the continent's 15 seaduck species (USFWS 1993, Goudie et al. 1994). These declines are poorly understood, and there is a need for new techniques to monitor populations. Typically, monitoring efforts focus on estimating total abundance. However, incorporating demographic data into monitoring programs can lend important insight into mechanisms underlying population change and help identify life stages at which changes are occurring.

Recruitment, the process by which young birds are added to the breeding population, is a crucial component of avian demographics. Thus, monitoring variation in recruitment rates is important from a management standpoint. Techniques traditionally used to assess waterfowl recruitment include pair:brood ratios (Kirby 1980, Rumble and Flake 1982), nesting success rates (Milne and Reed 1974, Klett et al. 1988) and age ratios based on wings turned in by hunters (Bellrose et al. 1961, Munro and Kimball 1982). Unfortunately, these techniques have been of limited value for many seaduck species, as most



FIGURE 1. Map of the study area in the Strait of Georgia, British Columbia, Canada. Circles indicate areas used to survey Surf Scoters during 2000, 2001, and 2002; squares indicate survey areas used during 2001 and 2002; triangles indicate survey areas used during 2000.

1 km of shore (Vermeer 1981), making winter populations readily accessible to researchers. Iverson et al. (2003) determined first-year males in these flocks can be reliably distinguished from adult males and females on the basis of plumage, raising the possibility that winter age ratios could be used as an index of recruitment. For this paper, our four primary research objectives were to (1) estimate Surf Scoter winter age and sex ratios in the Strait of Georgia, British Columbia, Canada, and document annual variation in population composition; (2) investigate the potential effects that age and sex-related differences in flock composition, habitat use, and latitudinal distribution patterns might have on age-ratio estimates; (3) determine the sample sizes required to detect changes in age ratios among years; and (4) discuss the advantages and disadvantages of using winter age ratio as an index of recruitment by Surf Scoters and perhaps other migratory bird species.

## METHODS

### STUDY DESIGN

The age and sex composition of Surf Scoter populations was investigated in the Strait of Georgia, British Columbia (Fig. 1), during the winters of 2000, 2001, and 2002. Three replicate surveys were conducted per year, at 10–14 day intervals, commencing the third week of January each year. During 2000, counts were made at 36 sample stations, encompassing seven survey areas (survey area defined as a bay, inlet, sound,

each survey area weighted according to sample size. Recruitment among waterfowl is commonly indexed as the ratio of first-year females to adult females (Cowardin and Blohm 1992). To facilitate comparison with literature values, sex ratio ( $M_{TOTAL}/F_{TOTAL}$ ) and male age ratio ( $M_{1Y}/M_{ADU}$ ) were also calculated. Female age ratio ( $M_{1Y}/[F_{TOTAL} - 2 M_{1Y}]$ ) was derived, based upon the assumption of a 1:1 ratio among first-year males and females. Annual variation in these parameters was assessed using ANOVA, with a 5 0.05. Specifically, we used a general linearized model ANOVA appropriate for our binomial data, with the Wald-statistic,  $W$  (StatSoft 1995).

*Flock composition patterns.* A typical assumption of a random sampling protocol to estimate age and sex ratios would be that the classes assort themselves randomly within flocks in the sampled population. To determine if this was the case with Surf Scoters, we challenged a null hypothesis that aged and sexed individuals were independently distributed (i.e., no overdispersion) and that there was no trend in age and sex composition with respect to flock size. These hypotheses were tested by regressing the proportion first-year male (first-year males:total males), and the proportion female (total females:total birds), against flock size, in separate analyses. We wished to know (1) whether members of either age class (first-year males versus adult males) or sex class (females versus males) tended to occur more frequently in flocks of a particular size, and (2) whether members of either age or sex class tended to occur in flocks composed predominately of like individuals.

To effect our analyses we treated each flock as an independent sample unit, yielding a sample size of  $n = 408$  for all years and replicates combined. These regressions used  $AIC_c$  and likelihood ratios to rank and test competing parametric hypotheses (Burnham and Anderson 2002) and were designed to respect the binomial error structure of the data by using a beta-binomial error distribution (Mood et al. 1985, McCullagh and Nelder 1989). The linear equations for the predicted proportions at each flock size were logit-transformed to retain the predictions within the range 0–1. Thus our statistical model was

$$p_{F_i} = \frac{1}{1 + e^{2(a + b \ln(F_i)) + 1_1 Y_{2001} + 1_2 Y_{2002}}} \quad 1 \ll_i$$

where  $0 \leq p_{F_i} \leq 1$  is the predicted proportion first-year male (or proportion female, depending

upon the analyses being performed) for flock  $i$  of  $n$  with  $F_i$  birds; and  $a$ ,  $b$ ,  $1_1$ , and  $1_2$  are parameters to be estimated. Variables  $Y_{2001}$  and  $Y_{2002}$

counts of first-year or adult males would contribute to observed overdispersion. Since we had no independent assessment of measurement error, we used our estimates of  $p_{F_i}$  and  $u^2_{F_i}$  to calculate the standard deviation of extrabinomial variance associated with each estimate of  $p_{F_i}$ . For these calculations we used

$$SD[p_{F_i}] = \sqrt{u^2_{F_i} p_{F_i} (1 - p_{F_i})}$$

derived from the ratio of variance of the beta-binomial to the binomial distribution. We then made an *a posteriori* judgment if measurement error was likely to be a significant contributor to the value of  $SD[p_{F_i}]$ .

**Habitat segregation.** To determine whether first-year males or females segregated into different habitats, midwinter survey counts were related to habitat attribute data. We used the British Columbia Marine Ecosystem Classification (BCMEC) for the Pacific Coast of Canada (Zacharias et al. 1998) to characterize the substrate and exposure for each sample station. For the BCMEC ecounit themes, substrate categorizations were taken from Geological Survey of Canada sediment distribution maps, with sites classified as *rocky*: bedrock, boulders, or cobble, with gravel/sand interspersed; *sandy*: sand or sand/gravel; or *muddy*: mud or sand/mud. Wind and wave exposure were categorized as *low*: protected area, fetch < 50 km; or *moderate*: open sound or strait, fetch 50–500 km. Variations in age and sex composition were investigated using the same ANOVA procedures described above for binomial data, where mean values were calculated for each survey area weighted according to sample size.

**Latitudinal variation.** Additional surveys were conducted during 2001 at locations along the Pacific coast to assess latitudinal variation in age and sex proportions. These surveys coincided with survey dates used in the Strait of Georgia and followed identical sampling protocols. They were conducted by volunteers with previous survey experience, whose assistance was solicited through birding organizations throughout the United States and Canada. Volunteers were trained using a website and written materials, which provided detailed instructions on identification of age classes and survey guidelines. Of 40 original respondents, 27 completed the three replicate surveys. Seven surveys were dropped due to insufficient sample size (< 40 total birds per survey) leaving an overall sample size of 20.

Simple linear regression was used to evaluate latitudinal trends in age and sex proportions for wintering aggregations ranging from 35–58°N.

**Power analysis.** To determine our power to estimate the proportion of first-year male Surf Scoters with a specified confidence and make recommendations for future study design, we used a bootstrap resampling scheme to generate confidence intervals for various sampling intensities. Our motivation was to determine the sample size required to confidently estimate this proportion, given the overdispersion observed in our data. Such overdispersion increases the size of the effective independent unit, thus proportionately increasing the sample size required to achieve a desired confidence interval. In our power analysis, flock composition data from all three years and replicate samples were treated both individually and pooled into a single dataset composed of 408 flock observations, containing 6422 total males.

Our first step was to perform a jackknife procedure (Efron and Tibshirani 1998) to estimate the mean proportion of first-year males  $\bar{p}_{F_1}$  and  $\bar{u}^2_{F_1}$ , as well as their standard errors ( $s_{\bar{p}_{F_1}}$  and  $S_{\bar{u}^2_{F_1}}$ , respectively) using the model equations described above, but with all parameters except  $a$  and  $c$  equal to zero. Our choice to use a jackknife procedure to calculate these moments was motivated by the variable flock sizes and overdispersion attributes related to flock size and habitat in our data, features not captured when these moments are estimated using sample statistics. Given estimates for these population moments, which we treated as known values, we could randomly sample first-year and adult males from flock

TABLE 1. Number of Surf Scoters observed in the Strait of Georgia, British Columbia, Canada, 2000–2002, by sex and age class. Values are means  $\pm$  SE for three replicate midwinter surveys.

	2000	2001	2002	Total
Total Surf Scoters	1221 $\pm$ 218	1316 $\pm$ 238	1080 $\pm$ 36	1206 $\pm$ 56
Total females	442 $\pm$ 66	422 $\pm$ 77	379 $\pm$ 23	414 $\pm$ 15
Total males	779 $\pm$ 152	894 $\pm$ 162	701 $\pm$ 12	791 $\pm$ 46
Adult males	680 $\pm$ 132	833 $\pm$ 150	629 $\pm$ 26	714 $\pm$ 50
First-year males	100 $\pm$ 21	62 $\pm$ 16	72 $\pm$ 14	78 $\pm$ 9
Proportion first-year males <sup>a</sup>	0.13	0.07	0.11	0.10
Sex ratio <sup>b</sup>	1.76	2.12	1.87	1.91
Female age ratio <sup>c</sup>	0.29	0.17	0.23	0.23

<sup>a</sup> The number of first-year males/the total number of males.

<sup>b</sup> The number of males/the number of females.

<sup>c</sup> The number of first-year males/(the number of females  $\times$  the number of first-year males).

tween these moments and flock size (i.e., only parameters  $a$  and  $c$  were estimated), contrary to what we will report in this manuscript. The reason for this is that (1) these relationships would not necessarily exist in other data collections, and (2) if they exist but are not identified, our power analysis will provide a conservative estimate of the sample size required to overcome the variance added by any such relationship. Means are presented  $\pm$  SE.

## RESULTS

*Age and sex ratios.* Similar numbers of Surf Scoters were counted each year, with survey means ranging from 1080  $\pm$  36 birds in 2002 to 1316  $\pm$  238 in 2001. Estimates for the proportion first-year males differed among years ( $W_2 = 41.6$ ,  $P < 0.001$ ), with annual estimates of 0.13  $\pm$  0.03 in 2000, 0.07  $\pm$  0.02 in 2001, and 0.11  $\pm$  0.02 in 2002. For males, these values yielded an overall age composition estimate of 0.10 first-year males:total males. With respect to sex, the population composition was strongly male biased, with an overall estimate of the proportion female of 0.35 total females:total birds. Annual variations were significant ( $W_2 = 5$

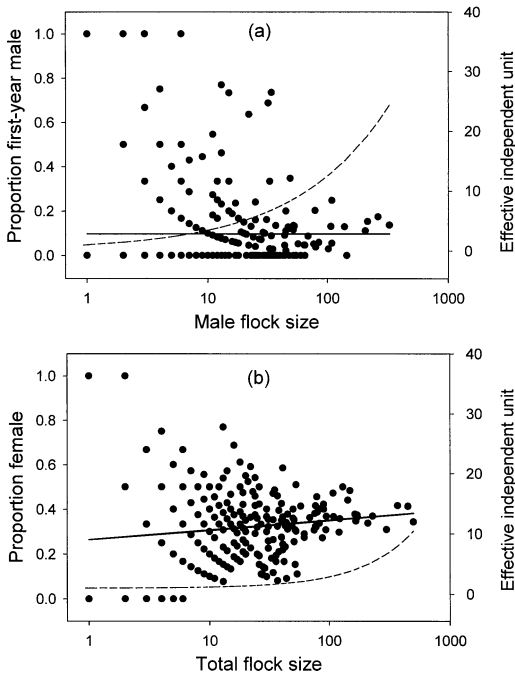


FIGURE 2. Relationship between Surf Scoter flock size and (a) proportion first-year male or (b) proportion female. Points indicate observed proportions, solid line indicates predicted proportions averaged over all years, and dashed line indicates the effective independent unit, a measure of the degree to which individuals in a given age or sex cohort tend to associate, and thus behave as a unit for statistical purposes. Interannual differences in the trends portrayed were statistically detected, but to retain clarity only the mean values are presented.

times more likely than its direct competitor lacking them, and thousands of times more likely than the null model (constant  $\hat{p}_F$  and  $\hat{u}_{F_i}^2$ ). The effective independent units differed only slightly from unity (complete independence) in the smallest flocks (averaged over all years 2000–2002), increasing to about 1.2 in flocks of 10 birds, then approximately 3 in flocks of 100. The standard deviation of extrabinomial variance

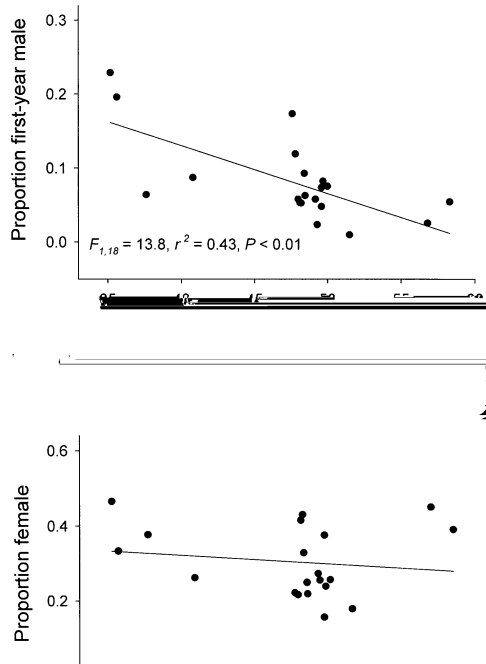


FIGURE 3. Geographic variation in age and sex composition of Surf Scoter flocks on the Pacific coast of North America. Data were collected during January and February 2001 by volunteers at 20 coastal locations between Alaska and California.

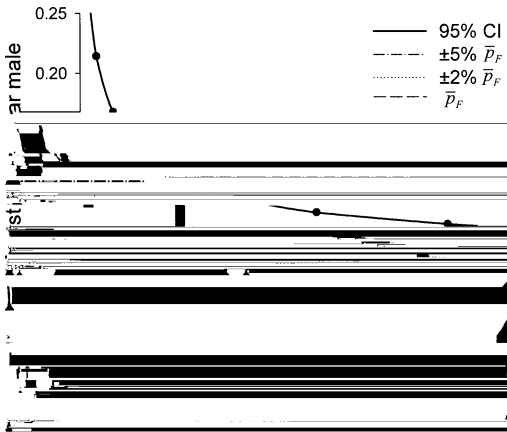


FIGURE 4. Number of sample stations and total number of male Surf Scoters necessary to estimate the proportion first-year male Surf Scoters ( $p_{F1}$ ) within



and 10–20% lighter than males (Palmer 1976), did not exhibit the same pattern. It should be noted, however, that we sampled only under relatively calm weather conditions, and it is possible that exposure-related distributional differences are more pronounced under extreme wind and wave conditions.

Our power analyses, which incorporated the tendency for individuals of various age and sex classes to associate with like individuals, and thus behave as a group for statistical purposes, were designed to assess the level of precision attainable at various sampling intensities. These analyses indicated that approximately 600–1000 total males were needed to obtain estimates within 5% of the population mean, and that precision could be further improved with larger samples, reaching roughly 2% from a sample of 6000 or more total males. While sampling intensities of such a magnitude would be logistically feasible in many areas, and could act as a guide for other researchers when designing monitoring programs, we caution that demographic parameters may differ among populations. Our analyses indicated that the sample size required to achieve a chosen level of confidence depends upon the mean age proportion, mean flock size, and overdispersion characteristics, all of which may vary from location to location.

While the potential estimation complications resulting from age-related differences in flock composition, overdispersion, and habitat association patterns can be remedied by sampling design, the data from volunteer surveys conducted at sites along the Pacific coast may present a greater challenge for the application of winter age ratios in population monitoring schemes and demographic models. This study was the first to investigate the possibility of differential migration according to age class among wintering seaducks. Latitudinal variation in Surf Scoter age ratios was evident, with a higher proportion of first-year male Surf Scoters wintering farther south. Differential migration is common among migratory birds, with prey and habitat differences, competitive exclusion by adults, and lower cold tolerance among young all potentially underlying geographic distribution patterns during winter (Cristol et al. 1999). If latitudinal variation in Surf Scoter winter age ratios exists, then estimates taken at a regional scale would be greatly complicated by interannual fluctuations in productivity in the larger population.

However, sample sizes in this part of the study were small, and there is a danger of committing a Type I error if too much credence is given to an extrapolation from a single year's observation. Future research will be necessary to evaluate the trend, determine if it is authentic, and if so investigate whether distributional differences are related primarily to site preferences by young or competitive exclusion by adults.

The potential for differential distribution of the age classes at a latitudinal scale during winter also raises the issue of how migratory populations are linked through the annual cycle, as migratory movements often confound efforts to delineate distinct population units for management purposes (Esler 2000, Webster et al. 2002). Population models most often focus on breeding aggregations, in part due to the direct implications for reproductive dynamics (Lindberg et al. 1998). Use of demographic data derived from wintering areas, however, requires that additional consideration be given to seasonal movements and potential linkages between breeding and nonbreeding areas.

Seaduck species exhibit a wide range of association patterns between breeding and nonbreeding areas. Common Eider (*Somateria mollissima*) populations, for example, are among the most geographically structured, with birds breeding in specific areas in arctic and western Alaska known to have separate wintering ranges (Petersen and Flint 2002). In such cases, age-ratio estimates made on wintering areas should correspond directly with productivity estimates from specific breeding locations. However, when migratory movements produce wintering aggregations which include multiple breeding populations, interpretation is more complex. For example, Pacific populations of Steller's Eiders (*Polysticta stelleri*) assort into three distinct breeding aggregations, but combine to form a single wintering population (Dau et al. 2000). Winter age ratios in such a population would represent a pooled estimate of productivity from multiple breeding areas, and would have to be treated as such in population models. Finally, for species such as Long-tailed Ducks (*Clangula hyemalis*), where little to no population structure has been identified (M. Petersen and P. Flint, unpubl. data), winter age ratios can serve only as a rough measure of age composition, with fine-scale linkages between specific breeding and wintering areas not being possible. To date, mi-

gratory movements and potential linkages between breeding and nonbreeding areas have not been elucidated for Pacific Surf Scoter populations. Therefore, caution must be applied when attempting to relate winter age-ratio estimates to productivity and recruitment estimates at specific breeding locations, and when extrapolating regional estimates to larger geographic scales during winter.

At present there is a clear need for new techniques to assess and monitor seaduck populations. Demographic data can be particularly useful for understanding the mechanisms underlying population changes. For species such as the Surf Scoter, which breed in low densities in remote portions of the continent, estimation of recruitment from winter age ratios offers an attractive alternative to traditional methods. Further, because distribution patterns can reveal important relationships to food resources, as well as adaptive social organization important to survival, understanding age- and sex-related differences is important from an ecological standpoint (Haramis et al. 1994). Results of this study suggest the use of male winter age ratios may be a practicable method for indexing recruitment by Surf Scoters; however, considerable care must be taken to plan for sample sizes that ascertain the desired precision of estimates. With such an effort, incorporating demographic data such as these into monitoring efforts and population models can better equip conservation agencies to understand declining seaduck populations and manage them for sustainability.

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