Management and Conservation Article

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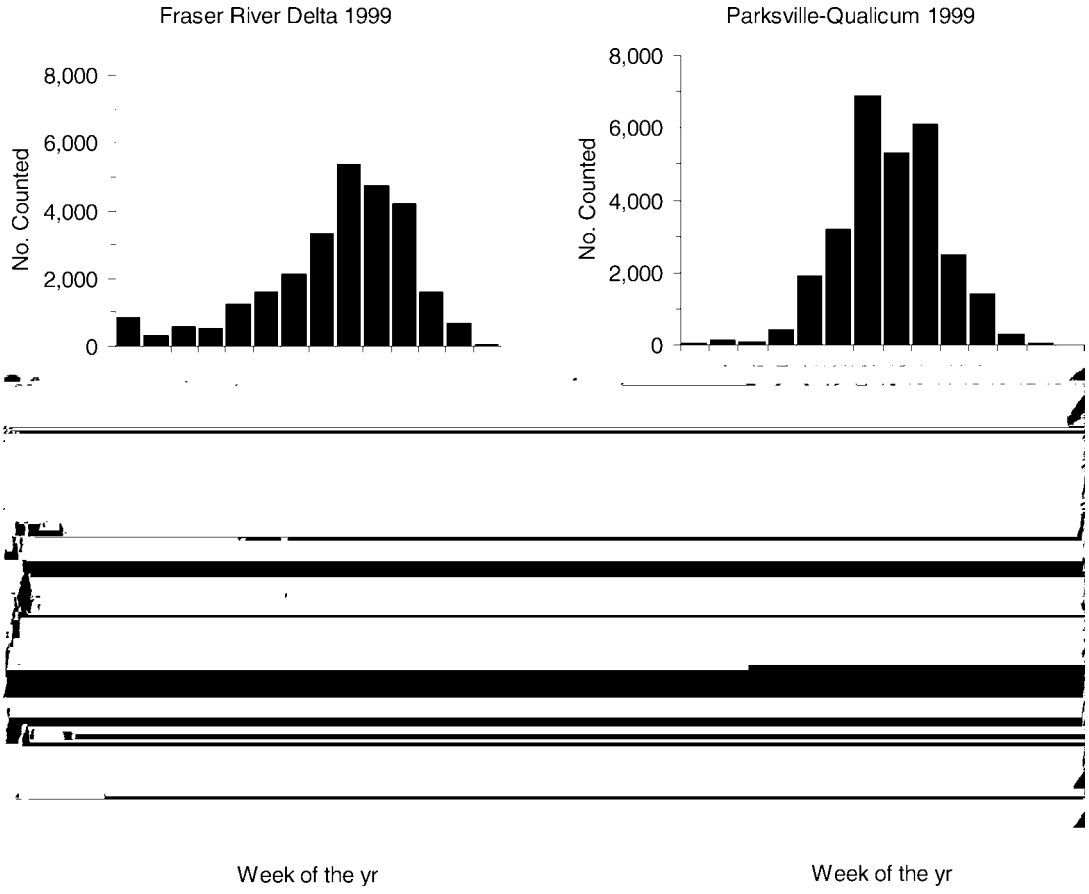
mid-February until the end of May, with those weekly periods corresponding across years and strata.

Before analysis, we divided the leg-band data into 2 groups and modeled them separately for each year. Group 1 contained band data for birds observed only once within a year (hereafter single-sight data), and group 2 contained data for birds observed multiple times (hereafter multi-sight data). Notwithstanding that we may have missed some single-sight birds during searches, these groups represented 2 qualitatively distinct staging patterns consistent with previous observations of brant staging in the Strait of Georgia (Routledge et al. 1999). Single-sight brant did not seem to use staging sites to accumulate body reserves but moved quickly through the area. Conversely, multi-sight birds staged for varying lengths of time, accumulating reserves for flight to and breeding on the Arctic nesting grounds. Using the multi-strata Recaptures Only option in MARK, we used 3 separate analyses for each year to estimate transition probabilities for the following movement segments: 1) single-sight A to B or C, 2) multi-sight A to B or C, and 3) multi-sight B or C to B, C, or D. (Note that single-sight B or C to D is equivalent to single-sight A to B or C, positively offset by 1 week, and that the multi-sight models accommodated the rare, but observed, transition between strata B and C.)

Model notation followed Cooch and White (2007) where p_{i}^{r} probability that a marked bird in stratum r at time



where w is the first week a marked bird was seen, i is week, and $P'_{A;i}$ is the probability that the marked bird arrived in week i or later if it had not been seen before w. We calculated $P'_{A;i}$ as

$$P'_{A;i} = P_{A;i} \prod_{j=i}^{} p_j^r$$

where

$$P'_{A;i} = \frac{P_i}{N - \sum_j}$$

i.e., the probability that the marked bird arrived in week i, given it had not arrived before i and p_i^r is the probability of a marked bird having been seen in week i 2, N, given that it was present. We estimated the standard error of A as follows:

$$S_A = \sum_i P'_{A;i} A$$

We calculated volume estimates for each stratum by summing the independently estimated numbers of single-sight and multi-sight brant that arrived each week. First, for each week we estimated the abundance from the count data and the proportion of birds that were classified as single-sight or multi-sight from the band observation data, which led directly to an estimate of the volume of single-sight brant

$$V_{SS} = \sum_i n_i \, pSS_i$$

where V_{SS} is the volume estimate for single-sight brant, n_i is the estimate of weekly abundance, and pSS_i is the proportion of single-sight brant in the week. Second, for each week we derived an estimate of the number of multi-sight brant from $M_i = (n_i)(pMS_i)$, where M_i is the number of multi-sight brant, n_i is the estimate of weekly abundance taken as the maximum daily count for that week, and pMS_i is the proportion of multi-sight brant in the week.

We estimated total volume of multi-sight brant using M_i and pR_i

$$V_{MS} = \sum_i \left(M_i \sum_j M_{i;j} pR_{i;j} \right)$$

such that the estimate of the volume of brant arriving over all weeks is

$$V_T = V_{SS} + V_{MS}$$

Error in the volume estimates arises from 2 independent

sources: 1) random counting error in abundance estimates and 2) statistical error in MARK's estimates of transition probabilities between strata. Concerning random counting error, there was no explicit measure of error for abundance estimates, because they were derived from the maximum daily counts for a particular week. To incorporate measurement error into our estimates, we simulated different degrees of counting error by imposing 3 percentages of random counting error encompassing a reasonable range of error (a 5 , 10 , and 20 CV). Second, we generated uncertainty in estimates of transition probabilities assuming a normal error distribution for MARK's logit-transformed Beta estimates for those probabilities. We then performed 1,000 randomizations of the Cholesky decomposed (square root) deviations of the c-adjusted covariance matrix of those Beta estimates to generate randomized volume estimates. Finally, we added uncertainty in the volume estimates arising from uncertainty in the transition probability estimates to the statistically independent measurement error associated with counts to calculate total uncertainty for the volume estimates.

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and the FRD. We observed very limited interchange between the strata (approx. 0.5 in 1999 and 3 in 2000).

We estimated similar volumes for 1999 and 2000 on stratum C (PQ), but volumes decreased between years on stratum B (FRD; Fig. 7). The PQ site hosted about 1,200 more brant than did the FRD site over both years, with approximately 15,000 brant hosted in PQ in both years. The FRD hosted about 9,000 brant in 1999 and 14,000 in 2000. Given the above-mentioned limited interchange between strata B and C, we consider the volumes for FRD and PQ to

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