ABUNDANCE ESTIMATES FOR FIVE POLAR BEAR POPULATIONS: A COMPARISON BETWEEN ESTIMATES DERIVED FROM PRELIMINARY AND EXTENSIVE DATA SETS

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The estimation of polar bear (*Ursus maritimus*) population abundance is essential for wildlife managers to assess conservation status and whether harvest is sustainable. With the added uncertainty of the impacts of climate warming on polar bear populations (Stirling and Parkinson 2006), it is critical to produce accurate, precise and timely abundance estimates. Providing accurate estimates for the world's 19 polar bear populations (Aars *et al.* 2005) is difficult and expensive. Multi-year mark-recapture (M-R) using physical capture is the method generally accepted to produce the most accurate and precise estimates of polar bear abundance (e.g., Derocher and Stirling 1995); however such studies in many regions are cost prohibitive. Abundance estimators using only two years of M-R effort (Lincoln-Petersen, L-P [Chapman 1951]; Manly-Parr, M-P [Manly and Parr 1968]) assume geographic and demographic closure and cannot generally incorporate co-variates and capture heterogeneity, resulting in biases of the population estimates. Manly *et al.* (2003) incorporated age information into an M-P analysis of simulated two-year data sets, thereby extending a closed model to incorporate a proxy for annual survival; yet gathering age information is not trivial for large data sets in terms of cost and personnel. Here we examine the bias of L-P–based abundance estimates of four polar bear populations (Baffin Bay, Gulf of Boothia, M'Clintock Channel and Viscount Melville, Figure 1) with respect to the estimates produced from analyses of extensive multi-year data sets using open estimators (McDonald and Amstrup 2001). These latter estimators incorporate age, sex and time specific survival, and recapture and recovery (*i.e.*, harvest) probabilities. We develop a simple empirical relationship between the two types of abundance estimates. Our second objective is to apply this empirical relationship to provide an estimate of a fifth population of polar bears, the Davis Strait population (Figure 1), for which only two years of current M-R data (without age information) exist. The abundance of the Davis Strait population has not been assessed since the 1970s (Stirling *et al.* 1980; Stirling and Killian 1980).

We use existing M-R data from Gulf of Boothia (Taylor *et al.* 2006b), M'Clintock Channel (Taylor *et al.* 2006a), Baffin Bay (McLoughlin *et al.* 2005) and Viscount Melville (Taylor *et al.* 2002) to generate L-P population estimates from two years of the M-R efforts. For each population, we provide abundance estimates for the year of marking based on the L-P model, which follows the Chapman (1951) correction, with several adjustments. First, we reduce capture heterogeneity with respect to sex (females have lower capture probability), by summing separate L-P estimates of male and female polar bears (and summing the variance). In a similar approach to Derocher and Stirling (1995) and Lunn *et al.* (1997), we project rather than estimate (Appendix I), the number of cubs-of-the-year (COY) and yearlings to reduce effects of capture heterogeneity among age-classes (Table 1). We then compare the L-P abundance estimates to the Burnham CJS estimates for the same year (Taylor *et al.* 2002; Taylor *et al.* 2005; Taylor *et al.* 2006a; b).

A pair-wise statistical comparison between the two types of estimates is trivial because the L-P should be smaller, as a Burnham CJS model can incorporate heterogeneity in capture probabilities to a greater extent than our adjusted L-P estimator. A positive bias may exist if there is immigration of unmarked individuals or if marked animals died disproportionately higher than unmarked individuals (Kendall 1999); however, assuming no behavioral bias with respect to the mark, the L-P estimate for the year of marking is unbiased with respect to survival. A correlation comparison of our adjusted L-P estimates to the more complex abundance estimates suggests a relatively constant and minor differential that is not influenced by the magnitude of the estimate (r = 0.99, y= 1.052x – 2.95).

To address our second objective, we derive an adjusted L-P estimate using the two years of M-R data collected in Davis Strait during the open-water seasons in 2005 and 2006 (Table 1). M-R data in Davis Strait were collected as for the other four populations (Taylor *et al.* 2002; Taylor *et al.* 2005; Taylor *et al.* 2006a; b), applying permanent marks (lip tattoos) using helicopter-based chemical immobilization and uniform area coverage; all polar bears encountered that can be caught safely are captured without regard to sex or age class. Recapture probability in Davis Strait in the second year (0.26) is higher than in Baffin Bay, M'Clintock Channel, and Gulf of Boothia, where recapture probability is 0.12, 0.12 and 0.10 respectively; recapture rate in Viscount Melville is similar, 0.25. The L-P abundance estimate for the Davis Strait polar bears is 2380 ± 186 (SE). Using the relationship between the L-P and the CJS estimates, the extrapolated number of bears in the Davis Strait region in 2005 was 2500 (Figure 2).

Here we provide a current abundance estimate for the Davis Strait polar bear population. The previous estimate (approximately 770 bears) from the late 1970s represented estimates summed from two portions of the Davis Strait population (Stirling *et al.* 1980; Stirling and Killian 1980), and were likely biased low due to capture methods. We conclude that our extrapolated two year mark-recapture study is sufficient to produce a working interim abundance estimate, given our comparative exercise. However, a minimum of three years of mark-recapture data are essential to estimate annual survival. Importantly, an estimate of survival will allow us to assess population growth and therefore, whether a continued harvest is sustainable.

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Table 1. Polar bears of different reproductive status caught and released in the Davis Strait population in 2005 and 2006.

Sex/Age-class/Family status	Number caught (frequency by yearly total)	
	2005	2006
Female coy	20 (0.032)	40 (0.048)
Female yearlings	15 (0.024)	34 (0.040)
Female sub-adults (2-5)	61 (0.098)	74 (0.088)
Female adults with no cubs	81 (0.130)	99 (0.118)
Female adults with 1 coy	22 (0.035)	22 (0.026)
Female adults with 2 coy	16 (0.026)	27 (0.032)
Female adults with 1 yearling	14 (0.022)	24 (0.029)
Female adults with 2 yearlings	13 (0.021)	25 (0.030)
Male coy	35 (0.056)	37 (0.044)
Male yearlings	26 (0.042)	39 (0.046)
Male subadults (2-5)	43 (0.069)	81 (0.096)
Male adults	277(0.445)	339 (0.403)
Total bears	623	841

Figure 1. The Baffin Bay, Davis Strait, Gulf of Boothia, M'Clintock Channel and Viscount Melville polar bear (*Ursus maritimus*) populations.

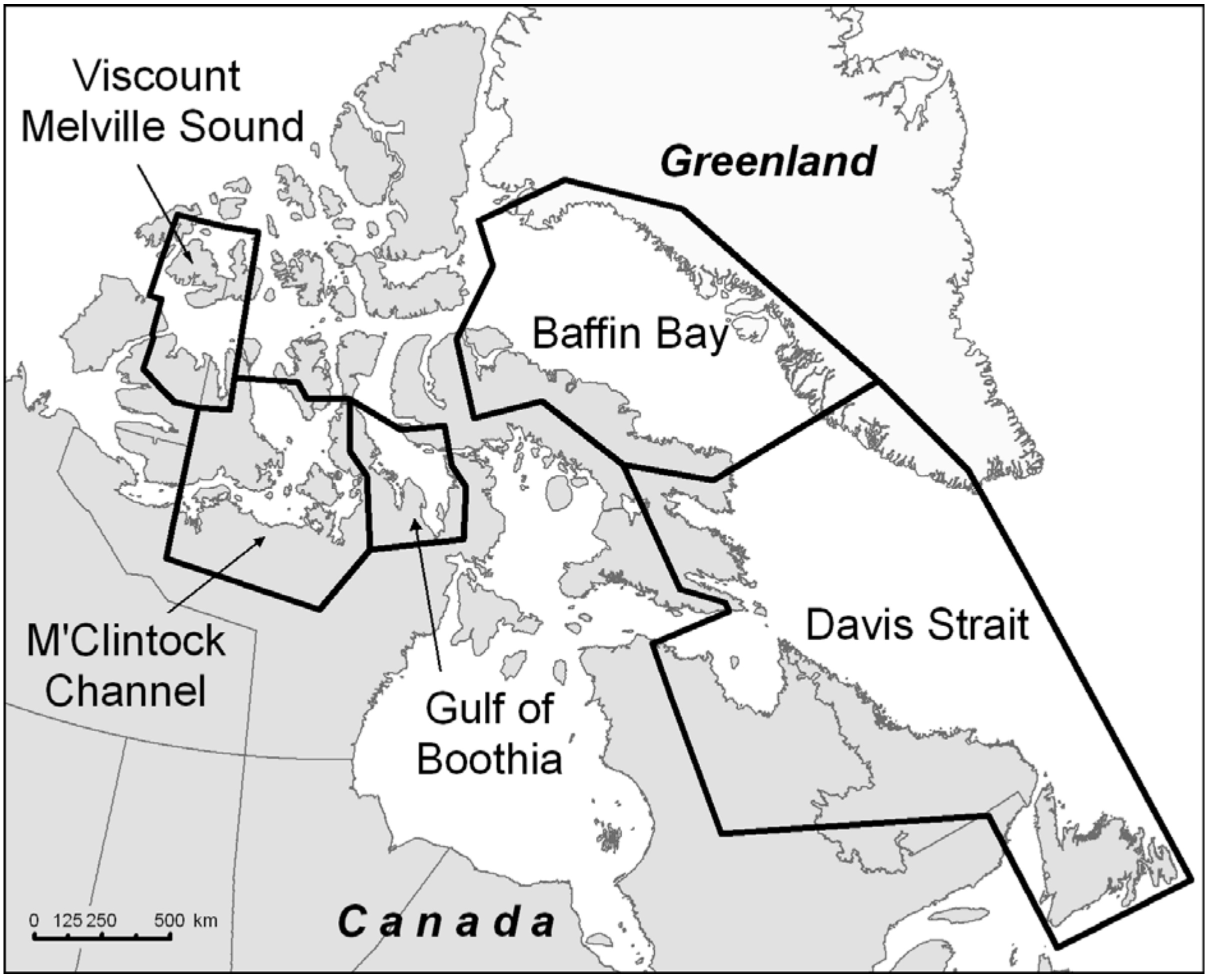
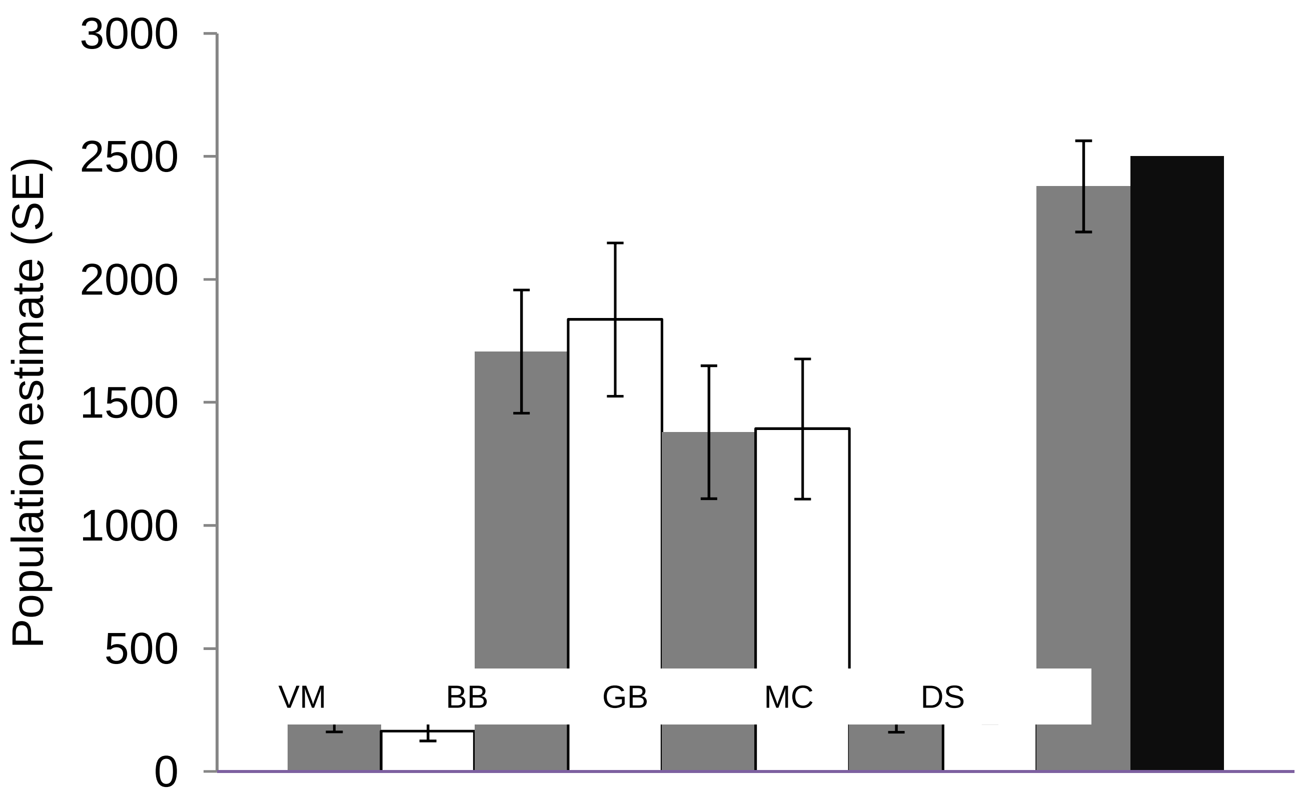


Figure 2. Population estimates (SE) for five polar bear populations in Canada. Gray bars represent Lincoln-Petersen estimates, based on 2 years of mark-recapture data; white bars represent CJS estimates using extensive data sets. The black bar represents the extrapolated Davis Strait (DS) estimate, based on the slope of the relationship between L-P and CJS of polar bears in Baffin Bay (BB), Gulf of Boothia (GB), M'Clintock Channel (MC) and Viscount Melville Sound (VM).



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Appendix I

The adjusted L-P estimate is generated from *post hoc* adjustments applied to the L-P estimators with Chapman (1951) correction: $T = N_{ind} + (N_{mf} * p_{coy}) + (N_{mf} * p_{yrl})$, where T is the total population size, N_{ind} the L-P estimate of the number of independent polar bears; N_{mf} is the sum of the L-P estimates of the number males and females, p_{coy} and p_{yrl} are the mean proportion of COY and yearlings, respectively, in annual capture samples; these proportions have associated SD. N_{ind} and N_{mf} have the associated SE of the L-P estimator (Chapman 1951). An algorithm for generating random variates from the distributions of the input values follows the polar method adapted from Law and Kelton (1991). Input values are sampled with Monte Carlo techniques from the distributions associated with N_{ind}, $N_{mf,}$ p_{coy} and p_{yrl}. The outcome is a normal distribution of T, with variance. The simulation was implemented in Microsoft Excel using the Visual Basic for Applications (VBA).