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.


STIRLING, I. and C.L. PARKINSON. 2006. Possible effects of climate warming on selected populations of polar bears (*Ursus maritimus*) in the Canadian Arctic. Arctic 59:261-275.


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

<table>
<thead>
<tr>
<th>Sex/Age-class/Family status</th>
<th>Number caught (frequency by yearly total)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2005</td>
</tr>
<tr>
<td>Female coy</td>
<td>20 (0.032)</td>
</tr>
<tr>
<td>Female yearlings</td>
<td>15 (0.024)</td>
</tr>
<tr>
<td>Female sub-adults (2-5)</td>
<td>61 (0.098)</td>
</tr>
<tr>
<td>Female adults with no cubs</td>
<td>81 (0.130)</td>
</tr>
<tr>
<td>Female adults with 1 coy</td>
<td>22 (0.035)</td>
</tr>
<tr>
<td>Female adults with 2 coy</td>
<td>16 (0.026)</td>
</tr>
<tr>
<td>Female adults with 1 yearling</td>
<td>14 (0.022)</td>
</tr>
<tr>
<td>Female adults with 2 yearlings</td>
<td>13 (0.021)</td>
</tr>
<tr>
<td>Male coy</td>
<td>35 (0.056)</td>
</tr>
<tr>
<td>Male yearlings</td>
<td>26 (0.042)</td>
</tr>
<tr>
<td>Male subadults (2-5)</td>
<td>43 (0.069)</td>
</tr>
<tr>
<td>Male adults</td>
<td>277 (0.445)</td>
</tr>
<tr>
<td>Total bears</td>
<td>623</td>
</tr>
</tbody>
</table>
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: \[ T = N_{ind} + (N_{mf} \cdot p_{coy}) + (N_{mf} \cdot p_{yrl}), \]

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).