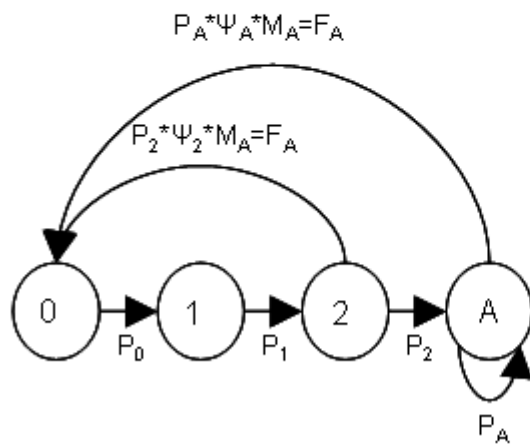Figure 4-1. Projection matrices and corresponding life cycle diagrams for age-structured matrix models of hoary marmot and collared pika population dynamics. Hoary marmots were modeled using four age classes (0, 1, 2, and A), and collared pikas were modeled using 2 classes (J and A). P_i, M_i, Ψ_i, and F_i terms represent age-specific survival, fecundity, breeding probability, and fertility for each of i age-classes.
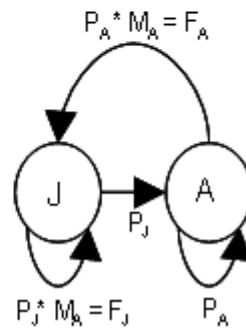
a.

$$A = \begin{bmatrix} 0 & 0 & F_2 & F_A \\ P_1 & 0 & 0 & 0 \\ 0 & P_1 & 0 & 0 \\ 0 & 0 & P_2 & P_A \end{bmatrix}$$

b.

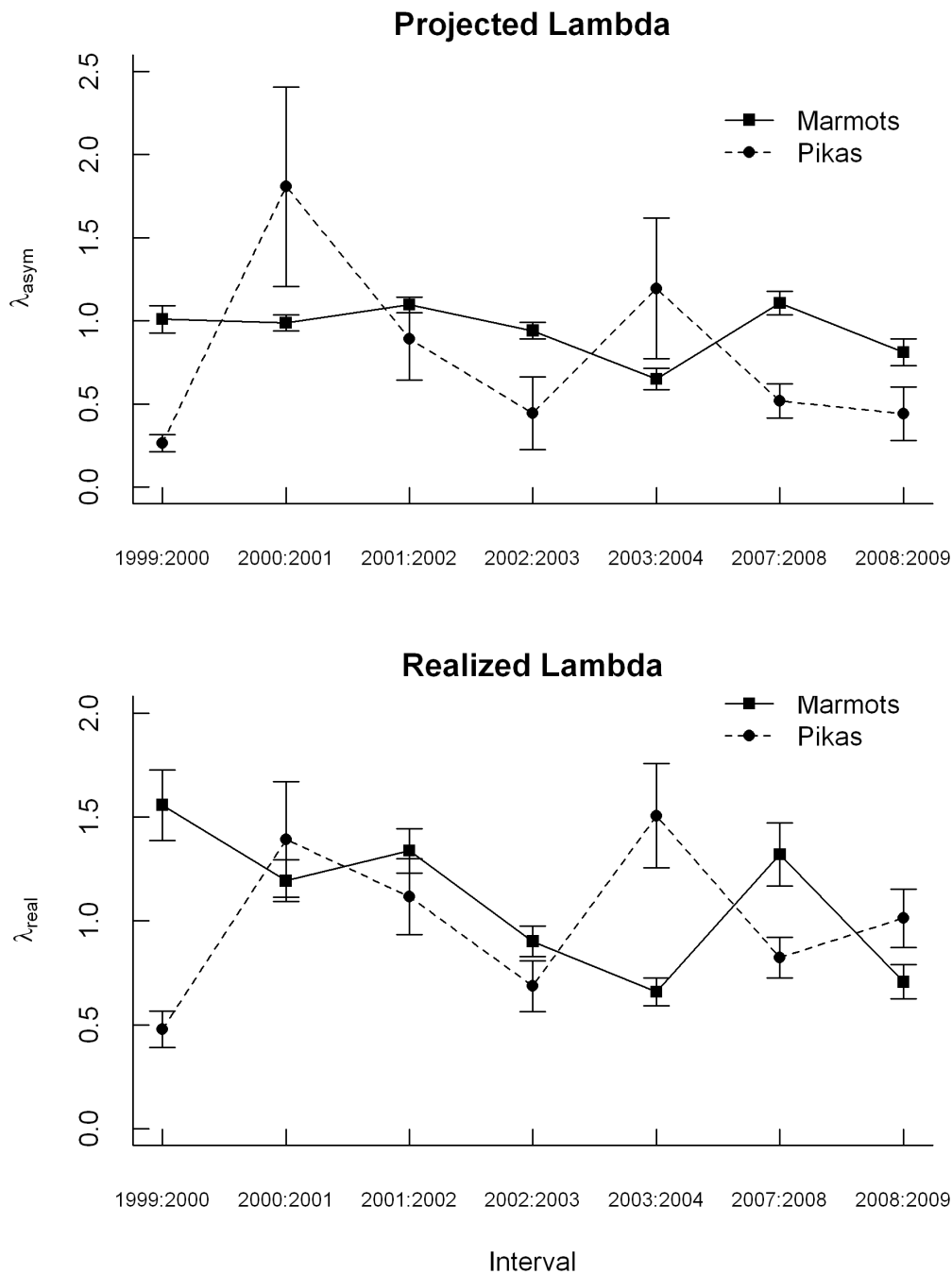$$A = \begin{bmatrix} F_J & F_A \\ P_J & P_A \end{bmatrix}$$

$$P_A * \Psi_A * M_A = F_A$$

$$P_2 * \Psi_2 * M_A = F_A$$

$$P_A * M_A = F_A$$

0 → 1 → 2 → A

P_0 P_1 P_2

P_A

J → A

P_J

$P_J * M_A = F_J$ P_A

2

Projected Lambda

Realized Lambda

Figure 4-2. Projected population growth rate (λ_{asym}) and realized population growth rate (λ_{real}) for hoary marmot and collared pika populations in the Ruby Range, Yukon, from 1999-2004 and 2007-2009. λ_{asym} values were derived from Leslie matrices, while λ_{real} was estimated using reverse-time mark-recapture models. Error bars represent 1 standard error. λ_{asym} standard errors were boostrapped, while λ_{real} standard errors were estimated using maximum-likelihood.
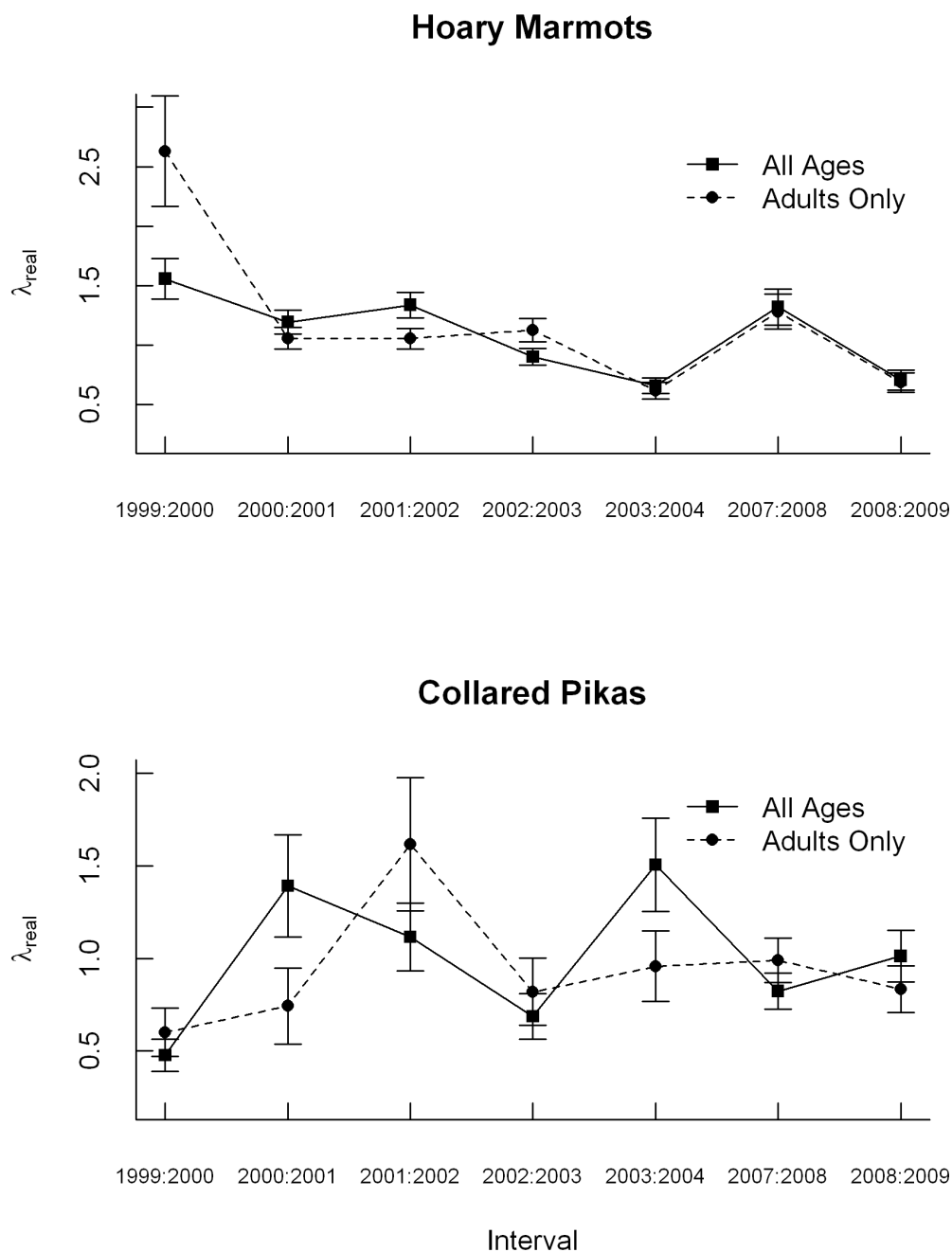
Hoary Marmots

Collared Pikas

Figure 4-3. Comparison of the realized population growth rate (λ_{real}) for all ages and for the adult age-class only, based on mark-recapture studies of collared pikas and hoary marmots in the Ruby Range, Yukon. Collared pika data are from 1999 through 2009, and hoary marmot data are from 1999 to 2004 and from 2007-2009. λ_{real} values were estimate using reverse-time mark-recapture models. Error bars represent 1 standard error.
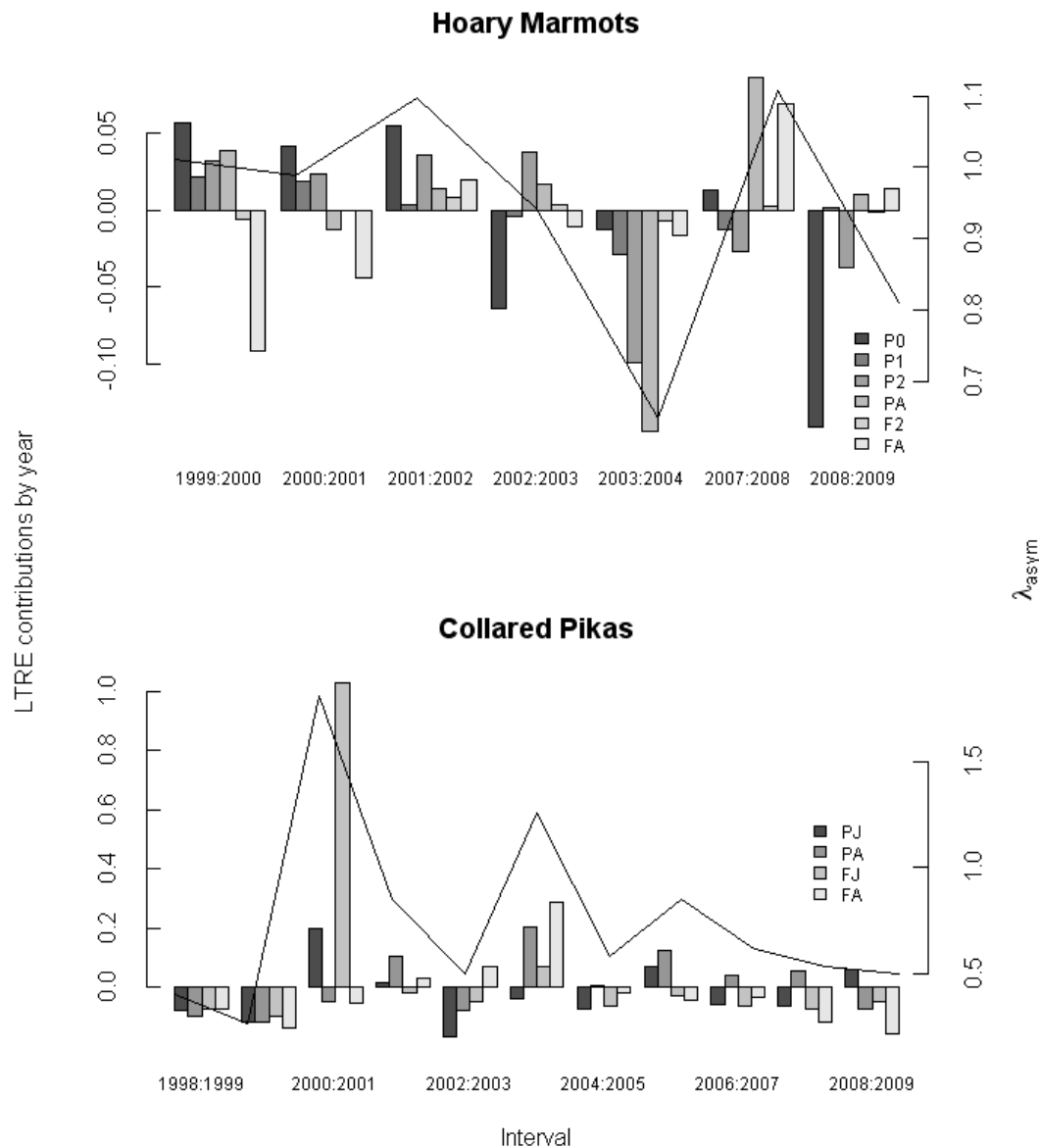
Figure 4-4. Results from Life Table Response Experiments based on long-term mark-recapture studies of hoary marmots and collared pikas in the Ruby Range, Yukon. The hoary marmot LTRE was based on population data from 1999-2004 and 2007-2009. The collared pika LTRE was based on data from 1998-2009. Each cluster of bars represents the proportional contributions made by age-specific demographic parameters to variation in projected population growth (λ_{asym}) during a specific overwinter interval. Contributions are plotted against the left y-axis. The hoary marmot models included six parameters (Juvenile survival = P_0, yearling survival = P_1, two-year-old survival = P_2, adult survival = P_A, two-year-old fertility = F_2, and adult fertility = F_A). The collared pika models included four parameters (Juvenile survival = P_J, adult survival = P_A, juvenile fertility = F_J and adult fertility = F_A The straight line shows the projected population

growth rate (λ_{asym}) for each interval, which is plotted against the right y-axis.
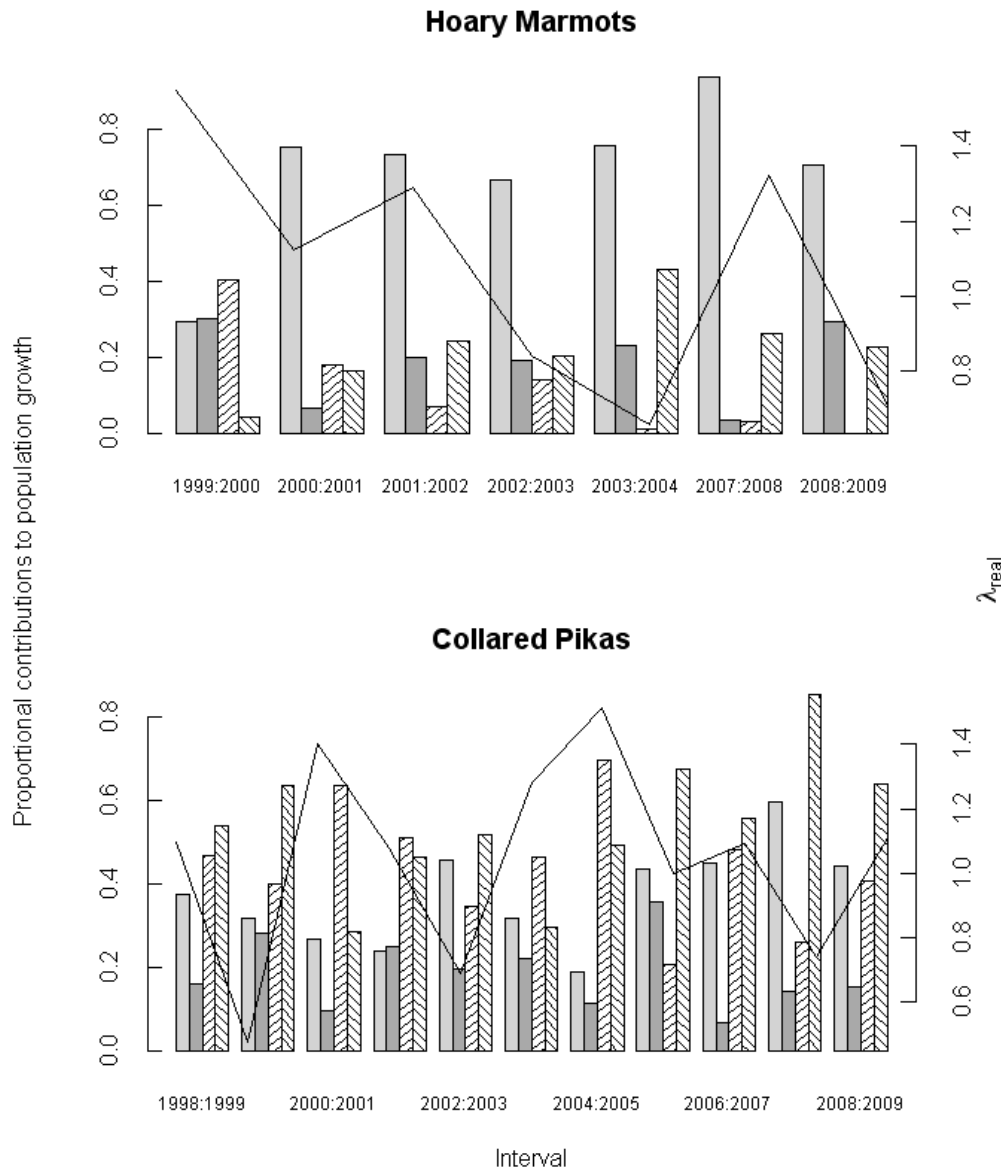

Figure 4-5. Proportional contributions of demographic parameters (Adult survival = AA, juvenile survival = AJ, apparent immigration = Imm, and reproductive parameters (breeding probability & fecundity) = Rep) to the realized population growth rate (λ_{real}) of the adult age class, in hoary marmot and collared pika populations from the Ruby Range, Yukon. The height of each bar (plotted against the left y-axis) represents the proportional effect of a unit change in that parameter on λ_{real}. Contributions were estimated using reverse-time modeling and methods described in Nichols et al. (2000). The solid line represents λ_{real} (for all age-classes combined), which is plotted against the right y-axis.
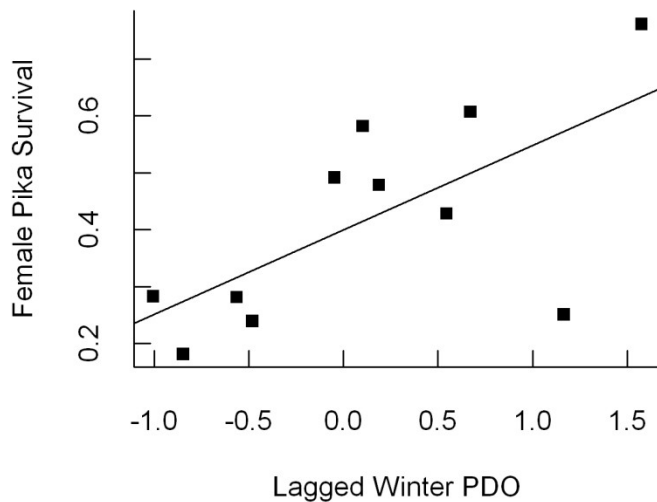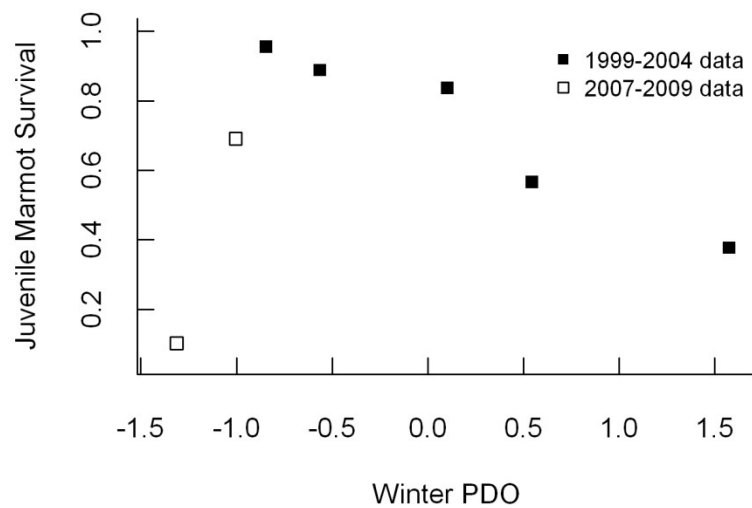
Figure 4-6. Relationships between survival parameters and the mean winter Pacific Decadal Oscillation (PDO) for hoary marmots and collared pikas in the Ruby Range, Yukon. The top panel shows winter PDO from the most recent winter plotted against the probability of juvenile hoary marmot overwinter survival. The bottom panel shows winter PDO lagged by one year plotted against adult female collared pika survival. Hoary marmot juvenile survival estimates are based on data collected between 1999 and 2004, and between 2007 and 2009. Collared pika estimates are based on data from 1998 to 2009. The solid line in the bottom panel represents the significant positive linear relationship between lagged winter PDO and ($R^2 = 0.37$, $p = 0.02$).

Literature Cited