Mourning Dove Banding Needs Assessment

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Introduction

The primary justification for an operational national mourning dove banding program is to provide data necessary for a long-term informed harvest management strategy as envisioned in the National Mourning Dove Strategic Harvest Management Plan (Anonymous 2005). This strategy requires development of demographic population models which in turn depend on estimates of population survival and recruitment rates as well as harvest rates. These estimates are derived wholly or in part from banding data.

Ideally, a formal banding needs assessment would be developed given an explicitly defined harvest strategy framework. At the current time such a strategy has not yet been completed. However, this assessment makes the logical assumption that any subsequent harvest strategy will require estimates of population vital rates and associated predictions of population growth rate, and this assumption provides the context for the proposed technique.

Methodology

Statistical objective

The assessment is based on the statistical objective of achieving a specified statistical precision of a running *k*-year average population growth rate ($\bar{\lambda}$). This criterion is based on the rationale that: 1) future harvest strategies are likely to depend directly on estimates of population growth rate, 2) statistical precision of $\hat{\bar{\lambda}}$ will be a function of the precision of both age- specific survival rate estimates, and 3) in 2-age class band recovery models used to estimate *S* and S', precision of $\hat{S}'$ depends on both AHY (adult) and HY (juvenile) sample sizes. In a predictive context, *VAR*($\hat{\bar{\lambda}}$) is composed of both process and sampling variation. Banding sample size affects only sampling precision, so logically the analysis will consider only this variance component. This is equivalent to considering *VAR* ($\hat{\bar{\lambda}}$) in a conditional or retrospective context, i.e., $VAR(\hat{\bar{\lambda}} \mid \bar{\lambda})$. Explicit structure of the underlying population model and associated vital rate sensitivity, as well as expressions for *VAR* ($\hat{\bar{\lambda}}$) are derived in Appendix A.

Optimum banding allocation in a stratified sampling framework

The relevant geographical scale for inference about $\bar{\lambda}$ is the mourning dove Management Unit (MU; Figure 1). If there are *t* strata in the MU, then $\hat{\bar{\lambda}} = \sum_{h=1}^{t} W_h \hat{\bar{\lambda}}_h$, where $\hat{\bar{\lambda}}_h$ is the estimate for the *h*th stratum and W_h is the stratum weight, which is proportional to the relative population abundance in the stratum. Appendix B describes the derivation of an expression for $E\left[VAR\left(\hat{\bar{\lambda}}_h\right)\right]$ as a function of stratum samples sizes for AHY and HY cohorts and independent values for the estimators of $\bar{P}$ and $VAR\left(\bar{P}\right)$. Given the stratum weights $\{W_h\}$, Appendix C describes derivation of optimum sample size formulas.

Recovery Rates

The precision of recovery rate estimates will also be directly affected by banding sample sizes. Harvest rate estimates are derived from recovery rate estimates corrected for reporting rate, and these harvest rates are likely to also play an important role in any subsequently derived harvest management strategy. Thus, information about the expected precision of harvest rate estimates given the optimum sample sizes based on a survival rate criterion is also relevant to the design of a long-term banding program.

Insight into the expected precision of recovery rates can be easily obtained by consideration of only direct recovery rate estimates, i.e., the proportion of birds banded and recovered in the same year. The expected value of the variance of this estimator is the simple binomial variance

$$E\left[VAR\left(\hat{f}_{direct}\right)\right] = \frac{f_{direct}\left(1 - f_{direct}\right)}{N},$$

which can be calculated using values derived from the sample size optimization technique above. Expected variance of a running *k* – year average direct recovery rate can be calculated as

$$E\left[VAR\left(\hat{\bar{f}}_{direct}\right)\right] = \frac{f_{direct}\left(1 - f_{direct}\right)}{N\,k},$$

assuming a constant recovery rate.

Derivation of State Banding Goals

For application of the above technique, we consider states as individual strata within MUs. Calculation of optimum banding sample sizes for each state requires values for state-specific survival and recovery rates, and absolute recruitment. Appendix D contains details about the origin of the values used in this assessment.

Spatial Allocation of Banding Effort within States

Given the banding goal for a state, a corollary issue is the spatial distribution of banding effort within the state. It is important to recognize that the primary objective of the banding program is to band a sample of birds that will result in accurate estimates of the survival and harvest rates of the state's breeding population. Selection of banding sites by use of a formal random sampling design would most likely produce unbiased estimates, but clearly this alternative is unrealistic given constraints of manpower and travel costs, restricted access to private land, etc. Conversely, choosing sites based only on convenience or minimum cost has the potential of resulting in significantly biased estimates.

The following guidance is proposed as a realistic compromise between these 2 alternatives. As a first step, the lower 48 states are stratified into physiographic regions defined by the Bird Conservation Regions (BCRs) developed for use in the North American Bird Conservation Initiative (Fig. 2; American Bird Conservancy 2009). These regional-scale landscapes are assumed to be highly correlated with mourning dove population density. Mourning dove density indices for each of the BCR strata that occur in each state were then calculated from annual Breeding Bird Survey (BBS) data (J. Sauer, U.S. Geological Survey, Pers. Comm.) and the median index value for the period 1966-2008 was used as the overall index to population density. The product of this BBS index and the area of the BCR were then used as the stratum index of population abundance, and these were used to calculate a set of stratum weights for each state (Appendix E). The banding goal for each stratum is then the product of the total state banding goal and the stratum weight.

The recommended number of banding locations within a stratum can be determined by using an approximate goal of 100 banded birds per banding degree block (~ 100 km * 100 km). The rationale is that this goal is large enough to justify expenditure of resources, but not so large as to result in over-weighting of a given block. The location of banding blocks and locations of specific sites within blocks is left to the expert judgment of the banding coordinator, based on considerations of cost and knowledge of expected hunting pressure. Establishment of permanent banding sites is encouraged, to help reduce temporal variation and cost over the longer term.

State Banding Goals

The statistical objective of estimation of a 5-year running average growth rate with expected standard deviation = 0.03 was chosen by the Eastern Management Unit. The Central and Western Management Units chose a 3-year running average with a standard deviation = 0.05. The resultant state goals, stratified by BCR region, are presented in Tables 1 – 3.

Discussion

This assessment represents the next phase of the initiative to establish a permanent mourning dove banding program that is enabled by a partnership between the USFWS and state wildlife agencies. Achievement of banding goals will be contingent on commitment of adequate resources from the state and federal partners. This assessment should be revisited at critical junctures in the development of new harvest strategies and in the evolution of the state/federal partnership for the conduct of monitoring programs in support of harvest management.

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Table 1. Banding goals for EMU states and BCR strata.

State	BCR	AHY	HY	AHY+HY
Alabama	24	57	76	
Alabama	27	373	493	
Alabama	28	124	164	
Alabama Total		554	733	1,287
Connecticut	30	75	71	
Connecticut Total		75	71	146
Delaware	30	15	14	
Delaware Total		15	14	29
Florida	27	63	61	
Florida	31	207	201	
Florida Total		270	262	532
Georgia	27	461	609	
Georgia	28	38	50	
Georgia	29	123	162	
Georgia Total		622	821	1,443
Illinois	22	539	661	
Illinois	23	10	12	
Illinois	24	121	149	
Illinois Total		670	822	1,492
Indiana	22	165	225	
Indiana	23	39	53	
Indiana	24	138	188	
Indiana Total		342	466	808
Kentucky	24	312	426	
Kentucky	28	48	66	
Kentucky Total		360	492	852
Louisiana	25	121	117	
Louisiana	26	106	103	
Louisiana	27	16	16	
Louisiana	37	63	61	
Louisiana Total		306	297	603
Maine	14	75	71	
Maine Total		75	71	146
Maryland	28	8	7	
Maryland	29	33	30	
Maryland	30	20	18	
Maryland Total		61	55	116
Massachusetts	14	10	9	
Massachusetts	30	66	62	
Massachusetts Total		76	71	147
Michigan	12	114	107	
Michigan	23	442	415	
Michigan Total		556	522	1,078
Mississippi	26	126	122	
Mississippi	27	198	192	
Mississippi Total		324	314	638

Table 1 (continued). Banding goals for EMU states and BCR strata.

State	BCR	AHY	HY	AHY+HY
New Hampshire	14	49	46	
New Hampshire	30	26	25	
New Hampshire Total		75	71	146
New Jersey	28	10	10	
New Jersey	29	15	14	
New Jersey	30	50	47	
New Jersey Total		75	71	146
New York	13	118	111	
New York	14	6	5	
New York	28	54	51	
New York	30	17	16	
New York Total		195	183	379
North Carolina	27	368	325	
North Carolina	28	19	17	
North Carolina	29	327	289	
North Carolina Total		714	631	1,345
Ohio	13	61	83	
Ohio	22	201	274	
Ohio	28	55	75	
Ohio Total		317	432	749
Pennsylvania	13	12	11	
Pennsylvania	28	95	85	
Pennsylvania	29	38	34	
Pennsylvania Total		145	130	275
Rhode Island	30	75	71	
Rhode Island Total		75	71	146
South Carolina	27	239	211	
South Carolina	29	88	77	
South Carolina Total		327	288	615
Tennessee	24	109	134	
Tennessee	27	105	129	
Tennessee	28	65	79	
Tennessee Total		279	342	622
Vermont	13	26	25	
Vermont	14	49	46	
Vermont Total		75	71	146
Virginia	27	51	45	
Virginia	28	67	59	
Virginia	29	118	104	
Virginia Total		236	208	444
West Virginia	28	99	89	
West Virginia Total		99	89	188
Wisconsin	12	21	26	
Wisconsin	23	357	438	
Wisconsin Total		378	464	843
Grand Total		7,297	8,061	15,358

Table 2. Banding goals for CMU states and BCR strata.

State	BCR	AHY	HY	AHY+HY
Arkansas	24	16	9	
Arkansas	25	28	16	
Arkansas	26	70	39	
Arkansas Total		114	64	178
Colorado	10	15	9	
Colorado	16	45	26	
Colorado	18	243	143	
Colorado Total		303	178	481
Iowa	11	108	93	
Iowa	22	590	508	
Iowa Total		698	601	1,299
Kansas	18	150	115	
Kansas	19	737	567	
Kansas	22	190	146	
Kansas Total		1,077	828	1,905
Minnesota	11	169	146	
Minnesota	12	12	10	
Minnesota	22	24	20	
Minnesota	23	89	77	
Minnesota Total		294	253	547
Missouri	22	126	71	
Missouri	24	52	29	
Missouri Total		178	100	278
Montana	10	28	29	
Montana	11	123	130	
Montana	17	384	403	
Montana Total		535	562	1,097
Nebraska	11	66	57	
Nebraska	18	115	99	
Nebraska	19	508	439	
Nebraska	22	84	73	
Nebraska Total		773	668	1,441
New Mexico	16	106	62	
New Mexico	18	114	67	
New Mexico	35	179	105	
New Mexico Total		399	234	633
North Dakota	11	578	499	
North Dakota	17	231	199	
North Dakota Total		809	698	1,507
Oklahoma	18	53	41	
Oklahoma	19	386	297	
Oklahoma	21	65	50	
Oklahoma	22	29	22	
Oklahoma	25	34	26	
Oklahoma Total		567	436	1,003

Table 2 (continued). Banding goals for CMU states and BCR strata.

State	BCR	AHY	HY	AHY+HY
South Dakota	11	572	494	
South Dakota	17	263	227	
South Dakota Total		835	721	1,556
Texas	18	188	145	
Texas	19	224	172	
Texas	20	129	100	
Texas	21	321	247	
Texas	25	76	59	
Texas	35	83	64	
Texas	36	196	151	
Texas	37	64	49	
Texas Total		1,281	987	2,268
Wyoming	10	64	67	
Wyoming	16	3	4	
Wyoming	17	85	90	
Wyoming	18	39	41	
Wyoming Total		191	202	393
Grand Total		8,054	6,532	14,586

Table 3. Banding goals for WMU states and BCR strata.

State	BCR	AHY	HY	AHY+HY
Arizona	16	263	162	
Arizona	33	1,291	799	
Arizona	34	515	319	
Arizona Total		2,069	1,280	3,349
California	5	20	17	
California	9	70	60	
California	15	24	20	
California	32	568	487	
California	33	251	215	
California Total		933	799	1,732
Idaho	9	335	266	
Idaho	10	18	14	
Idaho Total		353	280	633
Nevada	9	277	201	
Nevada	33	7	5	
Nevada Total		284	206	490
Oregon	5	55	44	
Oregon	9	217	172	
Oregon	10	63	50	
Oregon Total		335	266	601
Utah	9	204	148	
Utah	16	206	149	
Utah Total		410	297	707
Washington	5	11	8	
Washington	9	229	182	
Washington	10	39	31	
Washington Total		279	221	500
Grand Total		4,663	3,349	8,012

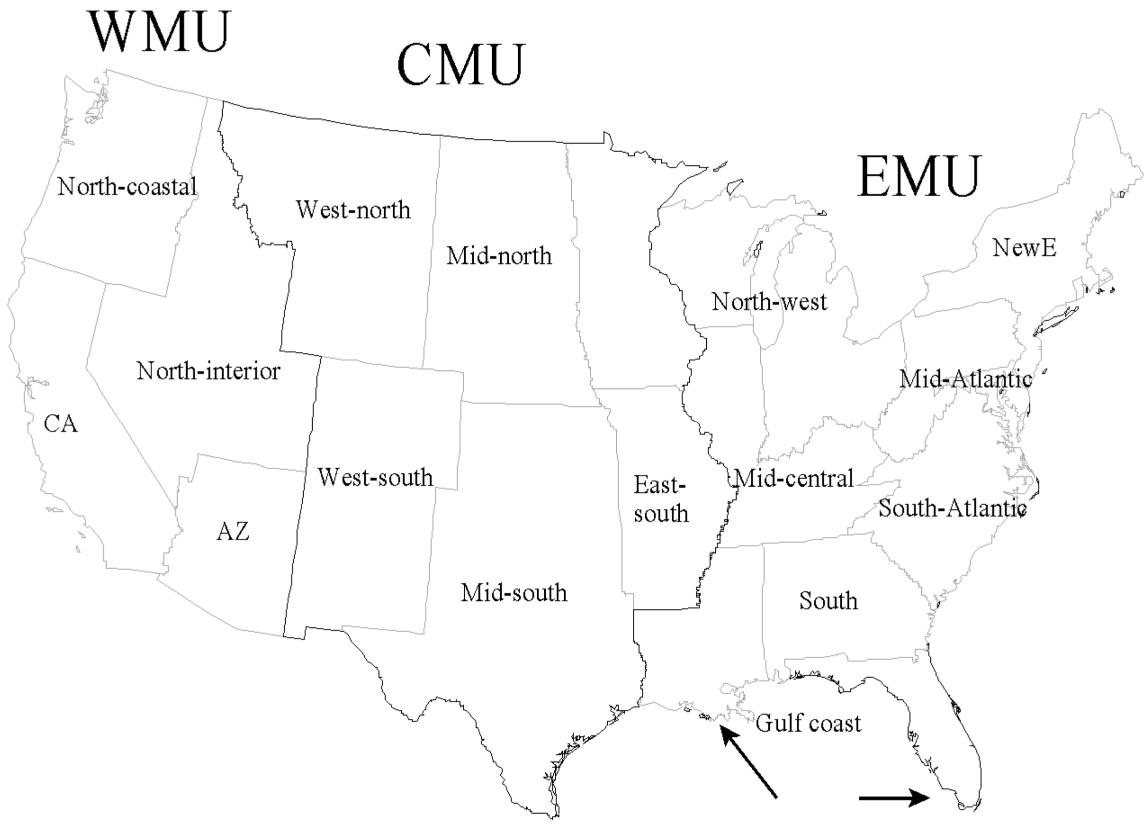
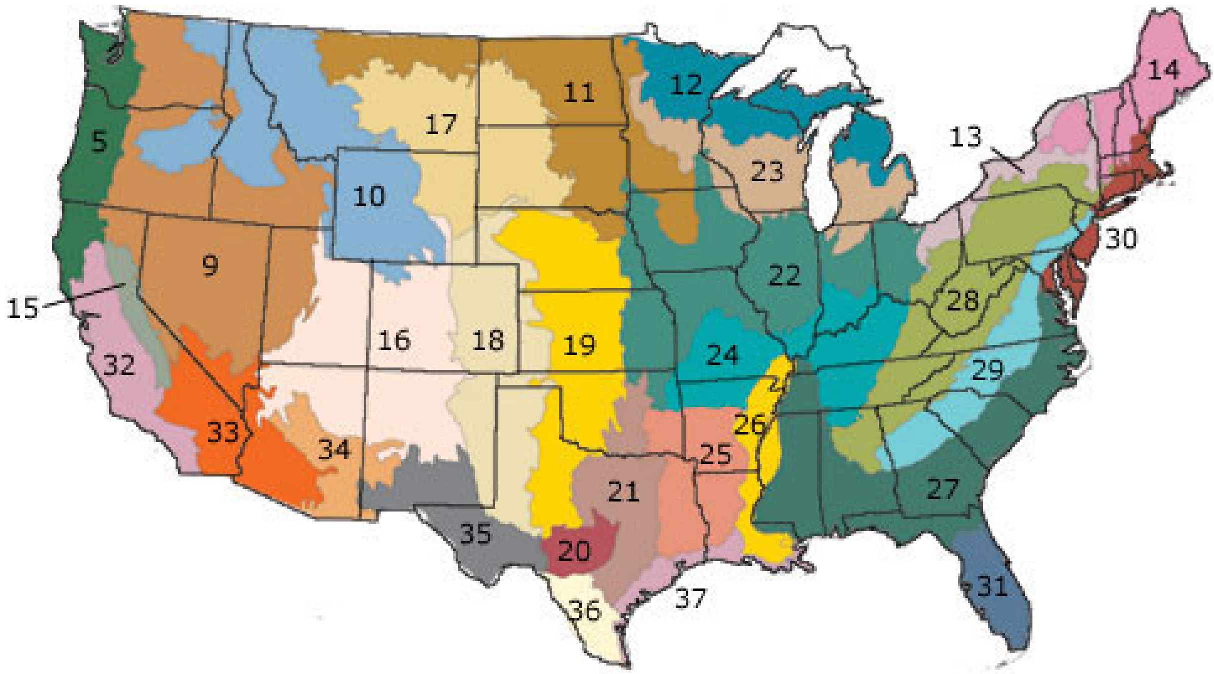


Figure 1. Geographical subregions used for analysis of mourning dove demographics.



5. Northern Pacific Rainforest
9. Great Basin
10. Northern Rockies
11. Prairie Potholes
12. Boreal Hardwood Transition
13. Lower Great Lakes/St. Lawrence Plain
14. Atlantic Northern Forest
15. Sierra Nevada
16. Southern Rockies/Colorado Plateau
17. Badlands and Prairies
18. Shortgrass Prairie
19. Central Mixed-grass Prairie
20. Edwards Plateau
21. Oaks and Prairies
22. Eastern Tallgrass Prairie
23. Prairie Hardwood Transition
24. Central Hardwoods
25. West Gulf Coastal Plain/Ouachitas
26. Mississippi Alluvial Valley
27. Southeastern Coastal Plain
28. Appalachian Mountains
29. Piedmont
30. New England/Mid-Atlantic Coast
31. Peninsular Florida
32. Coastal California
33. Sonoran and Mohave Deserts
34. Sierra Madre Occidental
35. Chihuahuan Desert
36. Tamaulipan Brushlands
37. Gulf Coastal Prairie

Figure 2. Bird Conservation Regions.

Appendix A.

Population Matrix Model

Consider a 2-stage post-breeding Lefkovich population matrix

$\underline{A}$ = $\begin{bmatrix} S'P & SP \\ S' & S \end{bmatrix}$, where S = AHY annual survival, S' = HY annual survival, P = annual recruitment. The matrix $\underline{A}$ refers to only the female population. Standard population matrix model analysis leads to formulae for the sensitivities $\underline{\Lambda}$ of the population growth rate λ to the parameters S', S, and P.

The sensitivity matrix is defined as

Σ = $\begin{bmatrix} \partial\lambda / a_{11} & \partial\lambda / a_{12} \\ \partial\lambda / a_{21} & \partial\lambda / a_{22} \end{bmatrix}$ = $\dfrac{\underline{v}^{T}\underline{w}^{T}}{\langle \underline{v}\underline{w} \rangle}$, where λ = population growth rate (dominant eigenvalue of $\underline{A}$), $\underline{v}$ = left (reproductive value) and $\underline{w}$ = right (stable age distribution) eigenvectors of $\underline{A}$.

A sensitivity vector $\underline{\Lambda}$ to lower level parameters S, S', and P is derived from

$\dfrac{d\lambda}{dx} = \sum\sum \dfrac{\partial\lambda}{\partial a_{ij}} \dfrac{\partial a_{ij}}{\partial x}$, which leads to

$\underline{\Lambda}$ = $\begin{bmatrix} (\partial\lambda / a_{11})P + \partial\lambda / a_{21} \\ (\partial\lambda / a_{12})P + \partial\lambda / a_{22} \\ (\partial\lambda / a_{11})S' + (\partial\lambda / a_{12})S \end{bmatrix}$, for the lower level parameters $\begin{bmatrix} S' & S & P \end{bmatrix}$.

However, it is straightforward to show that the matrix $\underline{A}$ has a simple closed form solution for the population growth rate

$$\lambda = S + S'P. \qquad \text{(A1)}$$

Thus, a simple alternative to traditional derivation of lower level sensitivities is to take the appropriate derivatives directly, leading to

$$\underline{\Lambda'} = \begin{bmatrix} P & 1 & S' \end{bmatrix} \tag{A2}$$

Banding effort obviously affects precision of annual survival estimates but does not affect precision of recruitment estimates. Therefore, Eq. (A2) could be used to justify an objective based on variance of HY survival ($S^{'}$), because a given absolute increase in $S^{'}$ causes a larger increase in λ than does an equivalent increase in AHY survival (S), assuming that $P > 1$.

However, the precision of estimates of both S and $S^{'}$ is affected by banding sample size and the parameter of interest is population growth rate. These considerations suggest use of the expression

$$\begin{aligned} VAR\left(\hat{\bar{\lambda}}\right) &= VAR\left(\hat{\bar{S}} + \hat{\bar{S}}'\hat{\bar{P}}\right) \\ &= VAR(\hat{\bar{S}}) + \bar{P}^2 VAR\left(\hat{\bar{S}}'\right) + \bar{S}'^2 VAR\left(\hat{\bar{P}}\right) + 2\,\bar{P}\,COV\left(\hat{\bar{S}}, \hat{\bar{S}}'\right) \end{aligned} \tag{A3}$$

as the basis for derivation of optimal sample sizes. Closed form expressions for annual survival rate variances and covariances from a standard time-specific band recovery model (Model H_1 in Brownie et al. (1985)) can be used to express Eq. (A3) as a function of annual banded sample size for AHY and HY age classes (Appendix B). The variance of the recruitment estimate $VAR(\bar{P})$ is obtained independently as described in Appendix D.

Appendix B.

In the following, N and M are the number of AHY and HY birds banded each year.

Derivation of VAR ($\bar{S}$)

$$VAR\left(\bar{S}\right) = \frac{1}{k^2}\left[\sum_{i=1}^{k} VAR\left(S_i\right) + 2\sum_{i=1}^{k}\ \sum_{j=1}^{k} COV\left(S_i, S_j\right), i \neq j\right]$$

Let

$$R_i = \bar{f}\left(\frac{1-\bar{S}^{k-i+2}}{1-\bar{S}}\right), i = 1, \ldots, k+1,$$

$$C_i = \bar{f}\left(\frac{1-\bar{S}^{\,i}}{1-\bar{S}}\right), i = 1,\ldots,k+1,$$

$$T_i = \frac{R_i\, C_i}{\bar{f}}, i = 1,\ldots,k+1.$$

Then, from Brownie et al. (1985),

$$E\left[VAR\left(\bar{S}\right)\right] = \frac{\bar{S}^2}{k^2\, N}\left[\sum_{i=1}^{k}\frac{1}{T_i - C_i} - \sum_{i=1}^{k}\frac{1}{T_i} + \frac{1}{R_1} + \frac{1}{R_{k+1}} - 2\right]. \qquad \text{(B1)}$$

Derivation of VAR ($\bar{S}'$)

$VAR\left(\bar{S}'\right) = \frac{1}{k^2}\sum_{i=1}^{k} VAR\left(S_i'\right)$, since $COV\left(S_i', S_j'\right) = 0, i \neq j$.

Then, from Brownie et al. (1985),

$$E\left[VAR\left(\bar{S}'\right)\right] = \frac{\bar{S}'}{k^2\, M}\sum_{i=1}^{k}\frac{1}{R_{i+1}} + \frac{\bar{S}'^2}{k^2\, N}\sum_{i=1}^{k}\frac{1}{R_{i+1}} - \bar{S}'^2 k\left(\frac{1}{M} + \frac{1}{N}\right). \qquad \text{(B2)}$$

Derivation of COV ($\bar{S}, \bar{S}'$)

$$COV\left(\bar{S}, \bar{S}'\right) = \frac{1}{k^2} COV\left(\sum_{i=1}^{k} S_i', \sum_{i=1}^{k} S_i\right).$$

Using results from Brownie et al. (1985), it can be shown that

$$E\left[COV\left(\bar{S}', \bar{S}\right)\right] = \frac{\bar{S}\,\bar{S}'}{N\, k^2}\left(\frac{1}{R_{k+1}} - 1\right). \qquad \text{(B3)}$$

Appendix C.

Derivation of optimum allocation formulas

We can use Eq. (A3) and combine terms from Eqs. (B1, B2, B3) to get

$\phi_h = \frac{c_{1h}}{N_h} + \frac{c_{2h}}{M_h} + \beta_h$, where

$$c_{1h} = \frac{\overline{S}_h^2}{k^2}\left(\sum_{i=1}^{k}\frac{1}{T_{hi}-C_{hi}} - \sum_{i=1}^{k}\frac{1}{T_{hi}} + \frac{1}{R_{h1}} + \frac{1}{R_{h,k+1}} - 2\right) + \overline{P}_h^2\,\frac{\overline{S}_h'^2}{k^2}\left(\sum_{i=1}^{k}\frac{1}{R_{h,i+1}} - k\right) + 2\,\overline{P}_h\,\frac{\overline{S}_h'\,\overline{S}_h}{k^2}\left(\frac{1}{R_{k+1}} - 1\right),$$

$$c_{2h} = \overline{P}_h^2\,\frac{\overline{S}_h'^2}{k^2}\left(\frac{1}{\overline{S}_h'}\sum_{i=1}^{k}\frac{1}{R_{i+1}} - k\right),$$

$$\beta_h = \overline{S}_h'^2\,VAR\left(\overline{P}_h\right).$$

Now,

$$\begin{aligned} VAR\left(\hat{\bar{\lambda}}\right) &= \sum_{h=1}^{t} W_h^2\,VAR\left(\hat{\bar{\lambda}}_h\right) \\ &= \sum_{h=1}^{t} W_h^2\left(\frac{c_{1h}}{N_h} + \frac{c_{2h}}{M_h} + \beta_h\right). \end{aligned} \qquad \text{(C1)}$$

For a desired $V = VAR\left(\hat{\bar{\lambda}}\right)$ we want optimum values of (N_h , M_h , h = 1, …, t). Using the Lagrangian multiplier technique:

Let $\Gamma = \sum_{h=1}^{t}\left(N_h + M_h\right)$ and consider the function

$$G = VAR\left(\hat{\bar{\lambda}}\right) + \rho\left(\sum_{h=1}^{t}\left(N_h + M_h\right) - \Gamma\right).$$

$$\frac{\partial G}{\partial N_h} = -\frac{W_h^2 c_{1h}}{N_h^2} + \rho = 0,$$

$$\frac{\partial G}{\partial M_h} = -\frac{W_h^2 c_{2h}}{M_h^2} + \rho = 0,$$

$$\frac{\partial G}{\partial \rho} = \sum_{h=1}^{t}\left(N_h + M_h\right) - \Gamma = 0.$$

Solving this system of equations,

$$N_h = W_h\sqrt{\frac{c_{1h}}{\rho}},$$

$$M_h = W_h \sqrt{\frac{c_{2h}}{\rho}} \,,$$

$$\Gamma = \sum_{h=1}^{t} \left(N_h + M_h \right) = \frac{1}{\sqrt{\rho}} \sum_{h=1}^{t} W_h \left(\sqrt{c_{1h}} + \sqrt{c_{2h}} \right)$$

And thus

$$N_h = \frac{W_h \sqrt{c_{1h}} \left(\sum_{h=1}^{t} \left(N_h + M_h \right) \right)}{\sum_{h=1}^{t} W_h \left(\sqrt{c_{1h}} + \sqrt{c_{2h}} \right)} = W_h \sqrt{c_{1h}} \frac{\Gamma}{\alpha}, \text{ where}$$

$$\alpha = \sum_{h=1}^{t} W_h \left(\sqrt{c_{1h}} + \sqrt{c_{2h}} \right).$$

Substituting into Eq. (9),

$$\begin{aligned} V &= \sum_{h=1}^{t} W_h^2 \left(\frac{c_{1h}\, \alpha}{W_h \sqrt{c_{1h}} \Gamma} + \frac{c_{2h}\, \alpha}{W_h \sqrt{c_{2h}}\, \Gamma} + \beta_h \right) \\ &= \frac{\alpha^2}{\Gamma} + \sum_{h=1}^{t} W_h^2\, \beta_h. \end{aligned}$$

Therefore,

$$\Gamma = \frac{\alpha^2}{V - \sum_{h=1}^{t} W_h^2\, \beta_h}. \qquad \text{(C2)}$$

and

$$N_h = W_h \sqrt{c_{1h}} \frac{\alpha}{V - \sum_{h=1}^{t} W_h^2\, \beta_h}, \qquad \text{(C3)}$$

$$M_h = W_h \sqrt{c_{2h}} \frac{\alpha}{V - \sum_{h=1}^{t} W_h^2\, \beta_h}. \qquad \text{(C4)}$$

Appendix D

In the following, each state within a management unit is considered as a separate stratum.

Survival and Recovery Rates

Band recovery data from states that participated in the national banding study during 2003 – 2007 were used to estimate age-specific survival and recovery rates. (Note: Data from Colorado, Utah and Wyoming were not analyzed because < 3 years of banding data were available.) These data were modeled using H_{02} in Brownie et al. (1985), which assumes time-constant and age-specific survival and recovery rates. Program MARK (White and Burnham 1999) was used to perform the calculations.

Data were analyzed at the subregion scale (Fig. 1), as defined by Otis et al. (2008), and then all states within the subregion were assigned the same parameter values. States that did not participate in the national banding study were assigned parameter values as follows:

i. OR, UT, NV = North-coastal subregion
ii. MT, WY = Mid-north subregion
iii. CO, NM = Mid-south subregions
iv. NewE (CT, MA, ME, NH, RI, VT), NY, NJ, MI = Northeast subregion estimates taken from Otis (2002)

Recruitment

Recruitment estimates were derived by correcting harvest age ratios for 2 sources of potential bias. First, unknown age wings were proportioned into age classes using a statistical estimation technique developed specifically for mourning doves (D. A. Miller, Iowa State University, pers. comm.). The data source for the correction factors was the molt stage and age class data collected during summer banding operations and fall wing collections conducted by 22 state agencies in 2005 – 2007. For those states that did not participate but that were in a subregion with 1 or more participating states, I used the average correction factor for the subregion. For subregions with no participating states, I used correction factors from subregions indicated in parentheses: North-coastal (Mid-north), North-interior (Arizona), West-north (Mid-north), West-south (Mid-south). These correction factors were then applied to uncorrected harvest age ratios derived from a national mail wing collection survey of hunters conducted in 2007 by the USFWS Harvest Survey Section.

A second correction factor was applied to each of the corrected state harvest age ratios to adjust for unequal harvest vulnerability between age classes. For each state, this factor was the appropriate subregion recovery rate ratio f_{HY}/f_{AHY}, taken from the Program MARK analysis described above. Finally, the variance of the recruitment estimate was computed by assuming that the correction factors were constants and using sampling variance formulas appropriate for ratios of binomial samples.

There is no data available for generating estimates of recruitment in non-hunting states. Therefore, recruitment for these states was chosen to be the value that resulted in $\lambda = 1$, using Eq. 1 in Appendix A and the survival rates in the previous section. The variance of the recruitment estimate was arbitrarily determined by assuming a $CV = 0.05$.

Appendix E

Stratum weights for allocation of banding effort within each state in the WMU and CMU. Stratum codes correspond to BCR codes in Figure 2.

WMU			CMU			CMU		
State	Stratum	Weight	State	Stratum	Weight	State	Stratum	Weight
WA	5	0.04	MN	11	0.57	TX	18	0.15
WA	9	0.82	MN	12	0.04	TX	19	0.17
WA	10	0.14	MN	22	0.08	TX	20	0.10
OR	5	0.16	MN	23	0.31	TX	21	0.25
OR	9	0.65	IA	11	0.16	TX	25	0.06
OR	10	0.19	IA	22	0.84	TX	35	0.06
ID	9	0.95	MO	22	0.71	TX	36	0.15
ID	10	0.05	MO	24	0.29	TX	37	0.06
NV	9	0.98	AR	24	0.14	MT	10	0.05
NV	33	0.02	AR	25	0.25	MT	11	0.23
UT	9	0.50	AR	26	0.61	MT	17	0.72
UT	16	0.50	ND	11	0.71	WY	10	0.33
CA	5	0.02	ND	17	0.29	WY	16	0.02
CA	9	0.07	SD	11	0.69	WY	17	0.44
CA	15	0.03	SD	17	0.31	WY	18	0.21
CA	32	0.61	NE	11	0.08	CO	10	0.05
CA	33	0.27	NE	18	0.15	CO	16	0.15
AZ	16	0.13	NE	19	0.66	CO	18	0.80
AZ	33	0.62	NE	22	0.11	NM	16	0.27
AZ	34	0.25	KS	18	0.14	NM	18	0.29
			KS	19	0.68	NM	35	0.44
			KS	22	0.18			
			OK	18	0.09			
			OK	19	0.68			
			OK	21	0.12			
			OK	22	0.05			
			OK	25	0.06			

Stratum weights for allocation of banding effort within each state in the EMU. Stratum codes correspond to BCR codes in Figure 2.

	EMU			EMU	
State	Stratum	Weight	State	Stratum	Weight
CT	30	1.00	GA	27	0.74
ME	14	1.00	GA	28	0.06
MA	14	0.13	GA	29	0.20
MA	30	0.87	AL	24	0.10
NH	14	0.65	AL	27	0.67
NH	30	0.35	AL	28	0.23
RI	30	1.00	MI	12	0.20
VT	13	0.35	MI	23	0.80
VT	14	0.65	OH	13	0.19
NY	13	0.61	OH	22	0.63
NY	14	0.03	OH	28	0.17
NY	28	0.28	IN	22	0.48
NY	30	0.09	IN	23	0.11
NJ	28	0.13	IN	24	0.41
NJ	29	0.20	WI	12	0.06
NJ	30	0.67	WI	23	0.94
PA	13	0.08	KY	24	0.87
PA	28	0.66	KY	28	0.13
PA	29	0.26	TN	24	0.39
MD	28	0.13	TN	27	0.38
MD	29	0.54	TN	28	0.23
MD	30	0.33	IL	22	0.80
DE	30	1.00	IL	23	0.02
WV	28	1.00	IL	24	0.18
VA	27	0.22	LA	25	0.40
VA	28	0.28	LA	26	0.35
VA	29	0.50	LA	27	0.05
NC	27	0.51	LA	37	0.20
NC	28	0.03	MS	26	0.39
NC	29	0.46	MS	27	0.61
SC	27	0.73	FL	27	0.23
SC	29	0.27	FL	31	0.77