U.S. Fish & Wildlife Service

Northern Pintail Harvest Strategy 2010

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PREFACE

The process of setting waterfowl hunting regulations is conducted annually in the United States (Blohm 1989). This process involves a number of meetings where the status of waterfowl is reviewed by the agencies responsible for setting hunting regulations. In addition, the U.S. Fish and Wildlife Service (USFWS) publishes proposed regulations in the *Federal Register* to allow public comment. This document is part of a series of reports intended to support development of harvest regulations. Specifically, this report is intended to provide waterfowl managers and the public with information about the strategy for setting northern pintail hunting regulations in the United States.

ACKNOWLEDGMENTS

This report was prepared by the USFWS Division of Migratory Bird Management. The principal authors were T. A. Sanders, M. C. Runge (U.S. Geological Survey), R. E. Trost, G. S. Boomer, and M. D. Koneff. M. C. Runge, G. S. Boomer, and T. A. Sanders developed the technical framework to support the current strategy. Significant contributions in developing the strategy were made by D. Yparraguirre (California Department of Fish and Game), S. E. Sheaffer (Cornell University), R. A. Malecki (Cornell University), R. E. Trost, K. Wilkins (USFWS), J. Dubovsky (USFWS), C. Moore (USFWS), D. Caithamer (USFWS), F. A. Johnson, and flyway biologists. Other individuals that provided essential information were K. Richkus (USFWS) and D. Caswell (Canadian Wildlife Servive). Comments regarding this document should be sent to the Chief, Division of Migratory Bird Management, U.S. Fish and Wildlife Service, 4401 North Fairfax Drive, MS MSP-4107, Arlington, VA 22203.

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EXECUTIVE SUMMARY

Over the past several years, scientists from the U.S. Geological Survey (USGS) and the USFWS, in consultation with the Flyway Councils, have collaborated on the development of an adaptive management framework to inform northern pintail (*Anas acuta*) harvest management. The proposed framework has been revised a number of times in response to comments and feedback from the Flyways. The USFWS and Flyway Councils adopted the adaptive harvest management protocol to inform harvest management decisions for northern pintails beginning with the 2010-2011 hunting season.

The purpose of the strategy is to identify annually an optimal, state-dependent regulatory alternative to best achieve the harvest management objective given regulatory alternatives and predictive models of system dynamics. The optimal regulatory strategies are calculated annually with: (1) an objective of maximizing long-term cumulative harvest subject to a constraint that provides an open hunting season when the observed breeding population is above 1.75 million birds; (2) a range of regulatory alternatives including a closed season, 1-bird daily bag limit, and 2-bird daily bag limit, with their predicted harvests; and (3) two predictive population models, one which posits additive harvest mortality and the other which assumes compensatory harvest mortality, and their relative weights. The derived northern pintail harvest strategy is state-dependent in that it specifies harvest regulations as a function of breeding population size and mean latitude of the breeding population. Model weights are updated annually by comparing model predictions with observed survey results to determine the predictive reliability of each alternative model. By iteratively updating model weights, the process should eventually identify which model (or balance of models) is the best overall predictor of changes in population abundance. This document describes the historical development and elements of the current northern pintail harvest strategy. Future changes and updates to the strategy will be documented in the annual Adaptive Harvest Management report available on our web site (http://www.fws.gov/migratorybirds/NewsPublicationsReports.html).

BACKGROUND

In 1995, the USFWS adopted the concept of adaptive resource management (Walters 1986) for regulating duck harvests in the United States (USFWS 2009a). This approach explicitly recognizes that the consequences of hunting regulations cannot be predicted with certainty, and provides a framework for making objective decisions in the context of that uncertainty (Williams and Johnson 1995, Williams et al. 2007). Inherent in the adaptive approach is an awareness that management performance can be maximized only if regulatory effects can be predicted reliably. Thus, adaptive management relies on an iterative cycle of monitoring, assessment, and decision-making to clarify the relationships among hunting regulations, harvests, and waterfowl abundance for the purpose of improving management over time.

Since at least 1995, the Flyway Councils have identified the northern pintail as a high-priority species for inclusion in the AHM process. The Pacific Flyway, which takes about 55% of the pintail harvest, has been especially supportive of this effort. The Pacific and Central Flyway Councils independently proposed prescribed harvest strategies for the 1996 season, but neither strategy was adopted by the USFWS (61 FR 38001, see Appendix A for publication details of pertinent Federal Register documents).

In July 1996, the Flyway Councils endorsed a resolution at the joint flyway meeting in Kansas City, Missouri (Joint Flyway Recommendation No. 13) that resulted in funding commitments from States and organizations in the Pacific and Central Flyways totaling $90,000 for incorporation of pintails into AHM. In 1997, the Pacific Flyway Council proposed a revised prescriptive harvest strategy and the Central Flyway Council reiterated its proposed strategy. The USFWS offered a revised version of the Pacific Flyway Council harvest strategy (62 FR 31303). This revised pintail harvest strategy was adopted in 1997 (62 FR 39721 and 50662).

Biologists in the Pacific Flyway are credited with developing the initial prescribed harvest strategy, but many have contributed to the strategy's initial and subsequent development, including biologists from State wildlife agencies, Flyway Councils, U.S. Fish and Wildlife Service, U.S. Geological Survey, and the New York Cooperative Fish and Wildlife Research Unit at Cornell University. Since adoption, the strategy has undergone review (USFWS 2002, Runge and Boomer 2005) and received technical modifications as additional data and insights became available.

The harvest strategy was revised in 2002 when Flyway-specific harvest models were updated (67 FR 40131). In 2002 and 2003, the Service set pintail regulations that deviated from the strict prescriptions of the harvest strategy (i.e., partial season), but remained true to the intent of the strategy (67 FR 53694 and 59111; 68 FR 50019 and 55786). In 2004, the harvest strategy was modified to include a partial season option (69 FR 43696 and 52971). In adopting those changes, the USFWS and others called for review of the pintail strategy (69 FR 57142) and consideration of technical modifications that could be made to improve it (see Runge and Boomer 2005). As a result of this review, the strategy was revised in 2006 to include updated flyway-specific harvest models, an updated recruitment model, and the addition of a procedure for removing bias in the breeding population size estimate based on its mean latitude (71 FR 50227 and 55656). Pursuant to requests from flyways and other stakeholders, a compensatory model was added to the strategy in 2007 (72 FR 18334, 31791, and 40198) as an alternative to the existing additive harvest model, and this update made the harvest strategy adaptive on an annual basis (USFWS 2007).

Throughout previous updates, the harvest strategy remained prescriptive; it used a rule-based process for annual, state-dependent regulatory decision making (Appendix B). The decision thresholds (i.e., rules for determining regulations) in the prescribed strategy were developed purposefully and imply underlying management interests, however, these interests have never been codified in an explicit statement of objectives. Lacking an explicit objective, it is difficult to justify the strategy's decision thresholds or to assess its performance. Also, frustration has arisen with this strategy because of the resulting non-intuitive decision thresholds, and its inability to accommodate changes in system dynamics. The Flyway Councils and USFWS have expressed interest in the development of a derived strategy based on specific management objectives since at least 2007 (USFWS 2007; 73 FR 30719 and 74 FR 16345).

Over the past two years, scientists from the U.S. Geological Survey (USGS) and the USFWS, in consultation with the Flyway Councils, have collaborated on the development of a derived framework for pintail harvest management. The draft framework has been revised a number of times in response to comments by the Flyways. In March 2010, the Flyway Councils recommended that the derived framework be adopted to inform pintail harvest management (75 FR 32873). The proposed adaptive harvest management protocol was adopted by the USFWS and Flyway Councils in June 2010 with implementation beginning with the 2010-2011 hunting season. The derived strategy differs from previous harvest strategies for northern pintails in that it: (1) is based on an explicit harvest management objective, (2) eliminates the partial season and 3-bird bag limit regulatory management options, (3) determines the annual regulatory choice based on a formal optimization process that finds the state-dependent solution to best achieve the harvest management objectives, and (4) allocates harvest on a national rather than Flyway-by-Flyway basis, with no explicit attempt to achieve a particular allocation of harvest among Flyways. Otherwise the proposed, derived harvest strategy incorporates the same system models as the prescribed strategy.

Future changes and updates to the strategy will be documented in the annual AHM report available on our web site (http://www.fws.gov/migratorybirds/NewsPublicationsReports.html).

PURPOSE AND OBJECTIVE

The purpose of this adaptive harvest management protocol is to inform harvest management decisions for northern pintails. The strategy identifies annually an optimal, state-dependent regulatory alternative to best achieve the stated harvest management objective based on a set of regulatory alternatives and models of system dynamics and their relative weights.

The stated harvest-management objective for northern pintails is to maximize cumulative harvest over the long term, which inherently requires perpetuation of a viable population. This objective is constrained to provide an open hunting season when the observed breeding population is above 1.75 million birds (based on the lowest observed breeding population size since 1985 of 1.79 million birds in 2002).

The single objective and constraint, in conjunction with the regulatory options (see next section), serve to integrate and balance multiple competing objectives for pintail harvest management, including minimizing closed seasons, eliminating partial seasons (shorter pintail season within the general duck season), maximizing seasons with liberal season length and greater than 1-bird daily bag limit, and minimizing large changes in regulations. These objectives relate directly or indirectly to more fundamental objectives that stakeholders have for pintail harvest management. These fundamental objectives include (1) conserve pintail populations indefinitely (a legal requirement under the Migratory Bird Treaty Act); (2) provide harvest opportunity; (3) minimize regulatory burden on the public; (4) encourage hunter participation; and (5) provide for other non-consumptive uses.

REGULATORY OPTIONS AND HARVEST

The adaptive protocol considers a range of regulatory alternatives that includes a closed season, 1-bird daily bag limit, and 2-bird daily bag limit. The maximum pintail season length depends on the general duck season framework (characterized as liberal, moderate, or restrictive and varying by Flyway) specified by mallard AHM (USFWS 2009a). Each regulatory combination of bag limit and season length has an associated predicted pintail harvest (described in the Technical Details section).

An optimal pintail regulation is calculated under the assumption of a liberal season length in all Flyways. However, if the season length of the general duck season determined by mallard AHM is less than liberal in any of the Flyways, then an appropriate pintail daily bag limit would be substituted for that Flyway. Thus, a shorter season length dictated by mallard AHM would result in an equivalent season length for pintails, but with increased bag limit if the expected harvest remained within allowable limits.

Regulatory substitution rules have been developed for the Central and Mississippi Flyways, where the general duck season length is driven by the mid-continent mallard AHM strategy (Table 1). These substitutions were determined by finding a pintail daily bag limit whose expected harvest was less than or equal to that called for under the national recommendation. Thus, if the national pintail harvest strategy called for a liberal 2-bird bag limit, but the mid-continent mallard season length was moderate, the recommended pintail regulation for the Central and Mississippi Flyways would be moderate in length with a 3-bird bag limit. Because season lengths more restrictive than liberal are expected infrequently in the Atlantic and Pacific Flyways under current eastern and western mallard AHM strategies, substitution rules have not yet been developed for these Flyways. If shorter season lengths were called for in the Pacific or Atlantic Flyway, then similar rules would be specified for these flyways and used to identify the appropriate substitution. In all cases, a substitution produces a lower expected harvest than the harvest allowed under the pintail strategy (Table 2).

Table 1. Substitution rules in the Central and Mississippi Flyways for joint implementation of northern pintail and mallard harvest strategies. The mid-continent mallard AHM strategy stipulates the maximum season length for pintails in the Central and Mississippi Flyways. The substitutions are used when the mid-continent mallard season length is less than liberal. For example, if the pintail strategy calls for a liberal season length with a 2-bird bag, but the mid-continent mallard strategy calls for a restrictive season length, the recommended pintail regulation for the Central and Mississippi Flyways would be restrictive in length with a 3-bird bag limit.

Pintail AHM regulatory option	Season length recommended by the mid-continent mallard AHM			
	Closed	Restrictive	Moderate	Liberal
Closed	Closed	Closed	Closed	Closed
Liberal 1	Closed	Restrictive 3	Moderate 3	Liberal 1
Liberal 2	Closed	Restrictive 3	Moderate 3	Liberal 2

Table 2. Expected total pintail harvest based on season length and daily bag limit in each Flyway. Calculations of expected harvest are described in the Technical Details section.

Flyway		
Pacific and Atlantic	Central and Mississippi	Total harvest
Closed	Closed	67,000[a]
Liberal 1	Closed	278,000
Liberal 1	Restrictive 3	410,000
Liberal 1	Moderate 3	523,000
Liberal 1	Liberal 1	569,000
Liberal 2	Closed	357,000
Liberal 2	Restrictive 3	490,000
Liberal 2	Moderate 3	603,000
Liberal 2	Liberal 2	672,000

[a] Expected harvest in Canada and Alaska

MODELS AND OPTIMIZATION

The adaptive protocol considers two population models. Each model represents an alternative hypothesis about the effect of harvest on population dynamics: one in which harvest is additive to natural mortality, and another in which harvest is compensatory to natural mortality. The compensatory model assumes that the mechanism for compensation is density-dependent post-harvest (winter) survival. The models differ only in how they incorporate the winter survival rate. In the additive model, winter survival rate is a constant, whereas winter survival is density-dependent in the compensatory model (described in the Technical Details section).

The population models rely on two state variables—the size and mean latitude of the northern pintail breeding population, as determined from the Waterfowl Breeding Population and Habitat Survey in the traditional survey area (USFWS 1987, 2009b). The observed breeding population size is adjusted to account for relative bias as a function of the mean latitude of the population (described in the Technical Details section). Pintail breeding population size and mean latitude also are used to predict pintail recruitment. The subsequent year's pintail breeding population size is predicted by the model-weighted average of the predictions from the additive and compensatory models of pintail population dynamics as a function of harvest (described in the Technical Details section). The models account for summer survival, predicted recruitment, predicted kill (comprising predicted harvest and crippling loss), and winter survival.

Model weights are updated annually by comparing model predictions with observed survey results to determine the predictive reliability of each alternative model. By iteratively updating model weights, the process should eventually identify which model (or balance of models) is the best overall predictor of changes in population abundance. The model with the greatest predictive ability will exert greater influence in regulatory decisions over time. Current model weights favor the hypothesis that harvest mortality is additive (60%).

Stochastic dynamic programming is used to find the state-dependent solution that best achieves the objective for northern pintail harvest management (Lubow 1995, Johnson and Williams 1999). This optimization process is based on: (1) the regulatory alternatives and associated predicted harvest; (2) current population models and their relative weights; and (3) the objective of maximizing long-term cumulative harvest subject to the closed-season constraint.

HARVEST STRATEGY

The derived northern pintail harvest strategy is state-dependent in that it specifies harvest regulations as a function of breeding population size and mean latitude of the breeding population. Graphical depiction of the strategy allows visual comparison of the effect of alternative additive, compensatory, and weighted additive-compensatory models (Figure 1).

At moderate population size and latitude, the strategy based on the compensatory model allows for greater harvest than does the strategy based on the additive model (Figures 1A and 1B) (note especially that the size of the liberal 1-bird bag region is smaller, thus, 2-bird bags are called for under more circumstances). The strategy based on the weighted (2010) model is intermediate between those based solely on the additive or compensatory models (Figure 1C). The regulatory consequences of the additive and compensatory harvest model weights on the resulting strategy are significant, and consequently adaptive resolution of the uncertainty is valuable. The threshold for season closure is consistent among all three models as a result of the constraint on the objective to provide an open hunting season when the observed breeding population is above 1.75 million birds.

Use of this regulatory strategy has been simulated to determine expected performance characteristics (Runge et al. 2009). Assuming that harvest management adhered to this strategy (and that current model parameters accurately reflect population dynamics), breeding-population size would be expected to average 2.9 million birds on the observed scale with a mean annual harvest of 468,000 birds. The expected frequency of closed seasons is 17% for the Pacific and Atlantic Flyways and 24% for the Central and Mississippi Flyways; and the frequency of liberal seasons with a 2-bird bag is 59% and 31%, respectively.

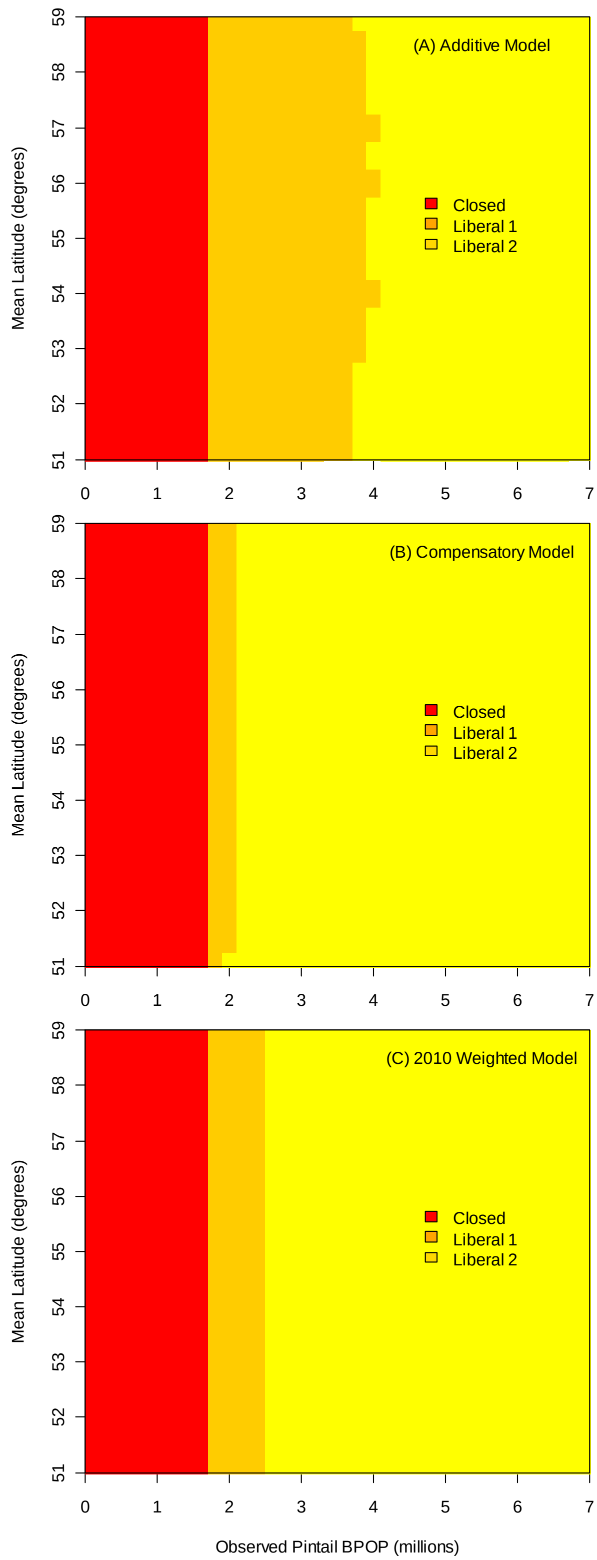

Figure 1. State-dependent harvest strategy with (A) additive, (B) compensatory, and (C) 2010 weighted models. In each case, the strategy assumes that the general duck season is liberal in season length. Regulatory options are closed, liberal 1-bird, or liberal 2-bird daily bag.

TECHNICAL DETAILS

The northern pintail harvest strategy depends on two current-year input variables determined from the Waterfowl Breeding Population and Habitat Survey in the traditional survey area (USFWS 2009b): breeding population size and mean latitude of the breeding population. Given these input variables, the procedure for identifying the maximum daily bag limit and season length for the upcoming hunting season involves the following calculations (Runge and Boomer 2005, Runge 2007).

Latitude Bias Correction Model

Northern pintails tend to settle on breeding territories farther north during years when the prairies are dry and farther south during wet years. When pintails settle farther north, a smaller proportion are counted during the Waterfowl Breeding Population and Habitat Survey, thus the population estimate is biased low in comparison to years when the birds settle farther south. This phenomenon may be a result of decreased detectability of pintails during surveys in northern latitudes compared to southern latitudes or because birds settle in regions not covered by the survey. The degree of overall bias appears to depend on the distribution of the pintail population among northern and southern strata, a distribution that is captured to a large degree by the mean latitude of the breeding population.

The latitude-adjusted breeding population size in year *t* ($cBPOP_t$) is calculated as

$$cBPOP_t = \exp\left(\ln oBPOP_t + 0.0741(mLAT_t - 51.68)\right) \qquad (1)$$

where $oBPOP_t$ is the observed breeding population size in year *t* and $mLAT_t$ is the mean latitude of the observed breeding population in year *t* (Runge and Boomer 2005).

The mean latitude of the northern pintail breeding population is the centroid or balance point for the traditional strata (1-50, 75-77) of the Waterfowl Breeding Population and Habitat Survey, and is the average latitude of survey strata weighted by abundance of the species in each survey strata. Mean latitude of the observed breeding population in year *t* is calculated as

$$mLat_t = \sum_j [l_j (oBPOP_{tj} / oBPOP_t] \qquad (2)$$

where l_j is the latitude of survey stratum *j*.

Population Models

Two population models are considered: one in which harvest is additive to natural mortality, and another in which harvest is compensatory to natural mortality. The models differ in how they incorporate the winter survival rate. In the additive model, winter survival rate is a constant, whereas in the compensatory model, winter survival is density-dependent.

The predicted, latitude-adjusted breeding population size in year *t* + 1 ($cBPOP_{t+1}$) for the additive harvest mortality model is calculated as

$$cBPOP_{t+1} = \left(cBPOP_t s_s (1 + \gamma_R \hat{R}_t) - \hat{H}_t / (1-c)\right) s_w \qquad (3)$$

where $cBPOP_t$ is the latitude-adjusted breeding population size in year *t*, s_s and s_w are the summer and winter survival rates, respectively, γ_R is a bias-correction constant for the age-ratio, *c* is the crippling loss rate, $\hat{R}_t$ is the predicted age-ratio, and $\hat{H}_t$ is the predicted continental harvest. Discussion of $\hat{R}_t$ and $\hat{H}_t$ submodels are found in the following sections. The model uses the following constants: s_s = 0.7, s_w = 0.93, γ_R = 0.8, and *c* = 0.2.

The compensatory harvest mortality model serves as a hypothesis that stands in contrast to the additive harvest mortality model, positing a strong but realistic degree of compensation. The compensatory model assumes that the mechanism for compensation is density-dependent post-harvest (winter) survival. The form is a logistic relationship between winter survival and post-harvest population size, with the relationship anchored around the historic mean values for each variable. For the compensatory model, predicted winter survival rate in year *t* (s_t) is calculated as

$$s_t = s_0 + (s_1 - s_0)\left[1 + e^{-(a + b(P_t - \bar{P}))}\right]^{-1} \qquad (4)$$

where s_1 (upper asymptote) is 1.0, s_0 (lower asymptote) is 0.7, *b* (slope term) is -1.0, P_t is the post-harvest population size in year *t* (expressed in millions), $\bar{P}$ is the mean post-harvest population size (4.295 million from 1974 through 2005), and

$$a = \text{logit}\left(\frac{\bar{s} - s_0}{s_1 - s_0}\right)$$

or

$$a = \log\left(\frac{\bar{s} - s_0}{s_1 - s_0}\right) - \log\left\{1 - \left(\frac{\bar{s} - s_0}{s_1 - s_0}\right)\right\} \qquad (5)$$

where $\bar{s}$ is 0.93 (mean winter survival rate) (Runge 2007).

Age Ratio Submodel

Predicted recruitment in year *t* (R_t) is measured by the vulnerability-adjusted female age-ratio in the fall population and is calculated as

$$\hat{R}_t = \exp\left(7.6048 - 0.13183 mLAT_t - 0.09212 cBPOP_t\right) \qquad (6)$$

where $mLAT_t$ is the mean latitude of the observed breeding population in year *t* and $cBPOP_t$ is the latitude-adjusted breeding population in year *t* (expressed in millions) (Runge and Boomer 2005).

Harvest Submodel

Predicted continental harvest in year t ($\hat{H}_t$) is calculated as

$$\hat{H}_t = H_{pf} + H_{cf} + H_{mf} + H_{af} + H_{akcan} \qquad (7)$$

where H_{pf} is predicted harvest in the Pacific Flyway, H_{cf} is predicted harvest in the Central Flyway, H_{mf} is predicted harvest in the Mississippi Flyway, H_{af} is predicted harvest in the Atlantic Flyway, and H_{akcan} is predicted harvest in Alaska and Canada and is a fixed value equal to 67,000 birds (the average harvest in Alaska and Canada from 1996 through 2003 was 65,910). Flyway specific harvest is calculated as

$$H_{pf} = -12051.41 + 1160.960 Days + 73911.49 Bag \qquad (8)$$

$$H_{cf} = -95245.20 + 2946.285 Days + 15228.03 Bag + 23136.04 Sis \qquad (9)$$

$$H_{mf} = -59083.66 + 3413.49 Days + 7911.95 Bag + 59510.10 Sis \qquad (10)$$

$$H_{af} = -2403.06 + 360.950 Days + 5494.00 Bag \qquad (11)$$

where *Days* is the season length, *Bag* is the daily bag limit, and *Sis* is an indicator variable with a value equal to 0 (full season equal to the season length from general duck season AHM) or 1 (restrictive season within the liberal or moderate regulatory alternative for general duck season AHM, i.e., partial season) (Runge and Boomer 2005).

Model Weights

The fit to historic data is used to compare the alternative additive and compensatory harvest models. From the $cBPOP_t$, $mLAT_t$, and observed harvest (H_t) for the period 1974 through year *t*, the subsequent year's breeding population size (on the latitude-adjusted scale) is predicted with both the additive and compensatory model, and compared to the observed breeding population size (on the latitude-adjusted scale). The mean-squared error of the predictions from the additive model (MSE_{add}) is calculated as

$$MSE_{add} = \frac{1}{(t-1975)+1} \sum_{t=1975}^{t} (cBPOP_t - cBPOP_t^{add})^2 \qquad (12)$$

and the mean-squared error of the predictions from the compensatory model is calculated in a similar manner.

The model weights for the additive and compensatory model are calculated from their relative mean-squared errors. The model weight for the additive model (W_{add}) is calculated as

$$W_{add} = \frac{\frac{1}{MSE_{add}}}{\frac{1}{MSE_{add}} + \frac{1}{MSE_{comp}}} \qquad (13)$$

The model weight for the compensatory model is found in a corresponding manner, or by subtracting the additive model weight from 1.0.

As of 2010, the compensatory model did not fit the historic data as well as the additive model (Figure 2). The mean-squared errors were 0.358 for the additive model and 0.527 for the compensatory model. Thus, the model weights, based on 2010 data, were 0.596 for the additive model, and 0.404 for the compensatory model.

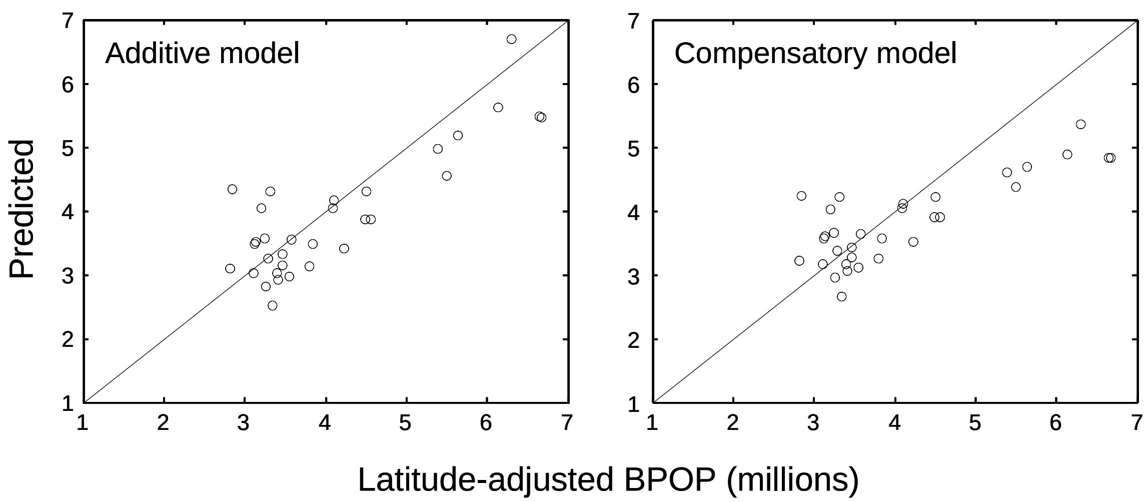

Figure 2. Predicted vs. observed breeding population size (latitude-adjusted), 1975–2010, for the additive and compensatory models.

The weighted average of the additive and compensatory models is then used to predict the size of the breeding population in the subsequent year as a function of harvest. Model weights are updated annually by comparing model predictions with survey results. By iteratively updating model weights, the process should eventually identify which model is the best overall predictor of changes in population abundance. The model with the greatest predictive ability exerts greater influence in regulatory decisions over time.

Other Calculations

Based on equations 2 and 3, predicted production in year *t* (r_t) may be calculated as

$$r_t = cBPOP_t s_s(\gamma_R R_t), \qquad (14)$$

predicted fall flight in year *t* (F_t) may be calculated as

$$F_t = cBPOP_t s_s (1 + \gamma_R R_t) \,, \tag{15}$$

and post-harvest population size in year t (P_t) may be calculated as

$$P_t = cBPOP_t s_s (1 + \gamma_R R_t) - H_t /(1 - c) \tag{16}$$

Yield Curves

Yield curves depict the sustainable annual harvest associated with a range of equilibrium population sizes; from these curves, both the carrying capacity and the maximum sustainable harvest can be discerned (Figure 3). The yield curve for the additive model suggests a continental carrying capacity of 7.32 million (on the latitude-adjusted scale), maximum sustainable harvest of 444,000 at an equilibrium population size of 3.34 million, and an optimal harvest rate (the harvest rate that produces the maximum sustainable yield) of 10.7% (Runge and Boomer 2005, Runge et al. 2009).

The yield curve for the compensatory model is significantly skewed compared to the additive model (Figure 3). On the right shoulder, as the harvest rate increases, the yield increases quickly with very little decrease in the equilibrium population size; thus, to some extent, the harvest is very nearly “free”. The maximum sustainable yield is higher for the compensatory model (560 thousand), but the implied continental carrying capacity is lower (4.67 million) and the optimal equilibrium population size is also lower (3.00 million). The optimal harvest rate is 14.8%.

The average model, weighted using 2010 data, produces a yield curve that is intermediate between the additive and compensatory models. On the right shoulder, the effect of harvest is less pronounced than in the additive model, but not as dramatically as in the compensatory model. The implied continental carrying capacity is 5.5 million (on the latitude-adjusted scale), the maximum sustainable yield is 487,700 at an equilibrium population size of 3.08 million, and the optimal harvest rate is 12.6%.

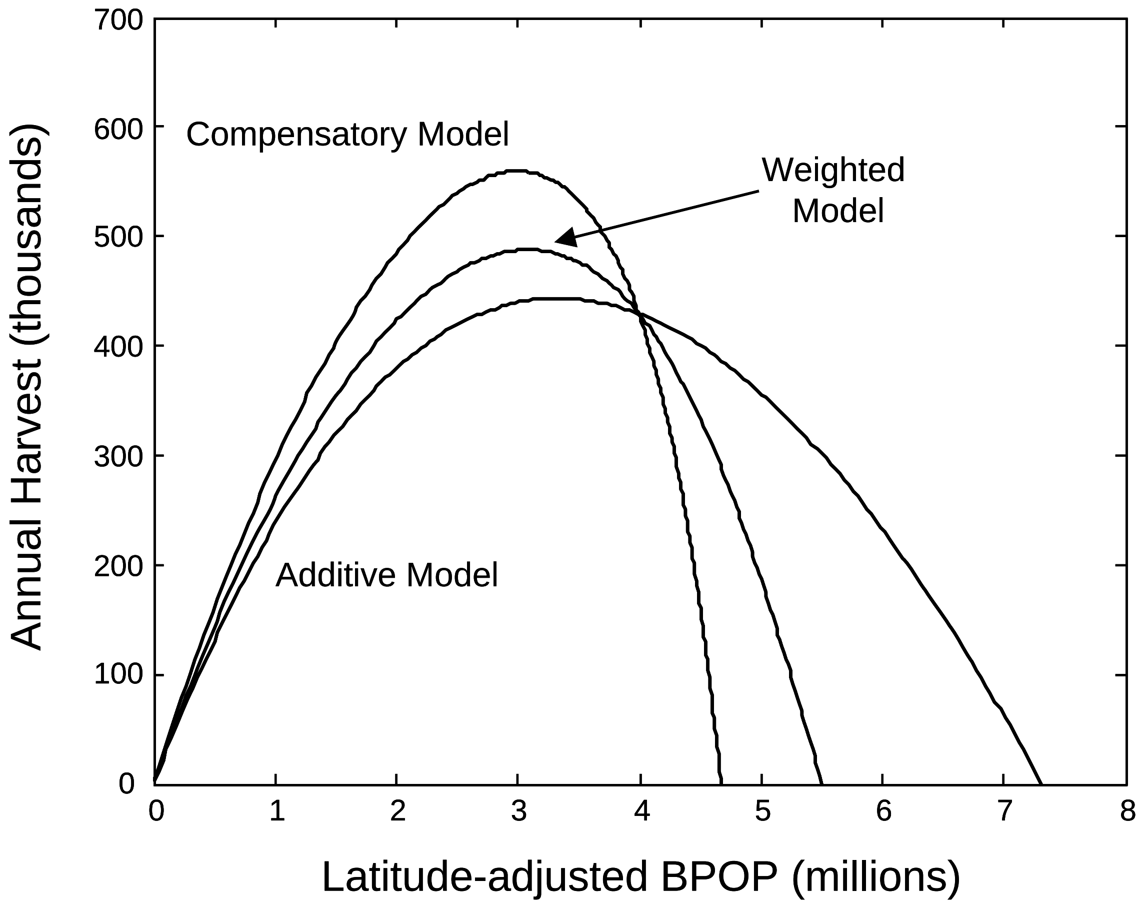

Figure 3. Equilibrium yield (sustainable annual harvest) curves for northern pintails under the additive, compensatory, and weighted (2010) models. Under the deterministic weighted model, the maximum sustainable annual harvest is 487,700, which occurs at an equilibrium population size of 3.08 million birds (on the latitude-adjusted scale).

LITERATURE CITED

Blohm, R. J. 1989. Introduction to harvest - understanding surveys and season setting. Proceedings of the International Waterfowl Symposium 6:118-133.

Johnson, F. A., and B. K. Williams. 1999. Protocol and practice in the adaptive management of waterfowl harvests. Conservation Ecology 3(1):8.

Lubow, B. C. 1995. SDP: Generalized software for solving stochastic dynamic optimization problems. Wildlife Society Bulletin 23:738–742.

Runge, M. C. 2007. Northern pintail harvest strategy: development of a compensatory model. Unpublished report.

Runge, M. C., and G. S. Boomer. 2005. Population dynamics and harvest management of the continental northern pintail population. (Final Report, June 6, 2005). U.S. Geological Survey, Patuxent Wildlife Research Center, Laurel, Maryland.

Runge M. C., G. S. Boomer, T. A. Sanders, and M. D. Koneff. 2009. Proposal for a derived and adaptive harvest strategy for northern pintails. U.S. Department of the Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Washington, D.C.

U.S. Fish and Wildlife Service. 1987. Standard operating procedure for aerial waterfowl breeding ground population and habitat surveys in North America. U.S. Department of the Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Washington, D.C.

U.S. Fish and Wildlife Service. 2002. Performance evaluation: Interim strategy for northern pintail harvest management. Unpublished report.

U.S. Fish and Wildlife Service. 2007. Northern pintail harvest strategy 2007. U.S. Department of the Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Washington, D.C.

U.S. Fish and Wildlife Service. 2009a. Adaptive harvest management: 2009 Hunting Season. U.S. Department of the Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Washington, D.C.

U.S. Fish and Wildlife Service. 2009b. Waterfowl Population Status. U.S. Department of the Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Washington, D.C.

Walters, C. J. 1986. Adaptive management of renewable resources. MacMillan Publ. Co., New York, N.Y.

Williams, B. K., and F. A. Johnson. 1995. Adaptive management and the regulation of waterfowl harvests. Wildlife Society Bulletin 23:430-436.

Williams, B. K., R. C. Szaro, and C. D. Shapiro. 2007. Adaptive management: the U.S. Department of the Interior technical guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC.

APPENDICIES

APPENDIX A. List of Federal Register documents pertinent to the northern pintail harvest strategy.

Publication date	Volume	Number	Page
July 22, 1996	61	141	38001
June 6, 1997	62	109	31303
July 23, 1997	62	141	39721
September 26, 1997	62	187	50662
June 11, 2002	67	112	40131
August 16, 2002	67	159	53694
September 19, 2002	67	182	59111
August 19, 2003	68	160	50019
September 26, 2003	68	187	55786
July 21, 2004	69	139	43696
August 24, 2004	69	163	52131
August 24, 2004	69	167	52971
September 23, 2004	69	184	57141
August 24, 2006	71	164	50227
August 22, 2006	71	184	55656
April 11, 2007	72	69	18334
June 8, 2007	72	110	31791
July 23, 2007	72	140	40198
May 28, 2008	73	103	30719
April 10, 2009	74	68	16345
June 10, 2010	75	111	32873

APPENDIX B. Purpose and objective statement from the earlier prescribed strategy used to guide harvest management decision for northern pintails during the 1997-1998 through the 2009-2010 hunting seasons.

The purpose of the prescribed northern pintail harvest strategy was to maintain harvest opportunity consistent with current population status while reducing acrimony about annual regulation setting by basing regulations on objective biological criteria. The objective was to identify the allowable daily bag limit between 1 and 3 that is consistent with the prescriptions of the strategy. Also, there was a desire to achieve a pintail population growth rate of at least 6% and to maintain a distribution of harvest among flyways consistent with “contemporary” levels (Pacific Flyway = 0.55, Central Flyway = 0.20, Mississippi Flyway = 0.20, and Atlantic Flyway = 0.05). Note that the strategy was prescribed, not derived; formal objectives were not explicitly articulated. Rather, the state-dependent strategy was calculated using a number of rules.

The strategy stipulated the regulations using the following considerations:

1) Except in certain circumstances (partial season), the pintail season length was determined by the general duck season length; and the pintail strategy was used to determine the bag limit.
2) The pintail season was closed when the observed breeding population (*oBPOP*) was less than 1.5 million and the predicted fall flight was less than 2.0 million.
3) A partial season (restrictive season length) was warranted when the *oBPOP* or predicted fall flight exceeded the closure level but the *oBPOP* was less than 2.5 million and the population model predicted a decline in the population size with a 1 bird bag under the full season length (liberal or moderate general duck season).
4) A full season, minimum 1-bird daily bag limit was called for when the *oBPOP* exceeded 2.5 million, regardless of the following year’s projection.
5) A full season with a 2- or 3-bird bag limit was called for when the model predicted population growth of at least 6% under the corresponding bag limit.

Thus, if the conditions for a season closure were not met, then the bag limit was at least 1 regardless of expected population growth in the subsequent year. If expected population growth of at least 6% could be achieved in the subsequent year with a 2- or 3-bird daily bag limit, then the larger bag limit was allowed. However, if the population was less then 2.5 million and a 1-bird bag in the otherwise moderate or liberal alternative was expected to result in negative population growth in the subsequent year then the season was restrictive (partial season within the general duck season).

APPENDIX C. Observed breeding population size (*oBPOP*), average latitude of the breeding population (*mLAT*), latitude-bias corrected breeding population size (*cBPOP*), observed continental harvest (*H*), and calculated post-harvest population size (*P*), for northern pintails, 1974–2010.

Year	*oBPOP*	*mLAT*	*cBPOP*	*H*	*P*
1974	6,598,182	53.062	7,307,829	1,413,293	7,189,268
1975	5,900,370	52.584	6,307,578	1,798,365	6,038,452
1976	5,475,644	53.231	6,140,947	1,545,202	5,881,464
1977	3,926,093	58.857	6,680,674	1,203,693	4,904,508
1978	5,108,179	52.689	5,503,408	1,491,598	5,575,118
1979	5,376,133	52.327	5,638,775	1,482,262	5,901,679
1980	4,508,077	56.936	6,653,333	1,233,913	5,343,338
1981	3,479,479	57.590	5,390,247	919,750	4,484,076
1982	3,708,758	53.060	4,107,088	908,331	4,638,775
1983	3,510,642	55.054	4,506,759	925,176	4,355,780
1984	2,964,801	56.029	4,091,130	786,518	3,836,120
1985	2,515,493	55.139	3,249,580	627,678	3,377,508
1986	2,739,747	54.852	3,464,880	529,462	3,812,512
1987	2,628,344	55.832	3,574,344	615,711	3,571,262
1988	2,005,522	59.064	3,465,380	279,230	3,252,767
1989	2,111,902	56.880	3,103,957	336,787	3,204,174
1990	2,256,630	57.807	3,552,465	318,263	3,500,418
1991	1,803,385	59.805	3,291,993	251,356	3,019,733
1992	2,098,139	57.659	3,266,848	260,287	3,320,399
1993	2,053,418	55.946	2,816,078	290,367	3,138,798
1994	2,972,266	53.563	3,416,491	360,447	4,346,230
1995	2,757,866	53.729	3,209,339	575,694	3,779,936
1996	2,735,862	53.509	3,132,169	585,367	3,740,614
1997	3,557,991	52.707	3,838,498	766,781	4,638,158
1998	2,520,649	55.392	3,317,995	645,455	3,367,856
1999	3,057,888	54.610	3,798,506	594,612	4,164,515
2000	2,907,559	57.739	4,554,211	553,807	4,160,560
2001	3,295,994	55.854	4,489,562	473,528	4,667,631
2002	1,789,710	57.910	2,838,906	380,437	2,700,155
2003	2,558,229	55.286	3,340,926	389,063	3,739,641
2004	2,184,602	56.498	3,121,080	372,038	3,253,216
2005	2,560,530	55.481	3,392,763	455,844	3,664,034
2006	3,386,425	54.676	4,227,175	476,859	4,747,881
2007	3,335,302	55.245	4,342,697	585,968	4,556,372
2008	2,612,841	58.214	4,239,186	587,459	3,731,618
2009	3,224,957	53.657	3,732,721	539,088	4,787,869
2010	3,508,558	54.420	4,297,371	†[a]	†

[a] Harvest data for 2010 was not available at time of publication and consequently post-harvest population size could not be calculated.

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