# Population Dynamics and Harvest Management of the Continental Northern Pintail Population

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## 1. Executive Summary

Pursuant to requests from the Service Regulations Committee and the Pacific Flyway Council, we reviewed available information about northern pintail (*Anas acuta*) demography, population dynamics, and harvest. Based on this review, we suggest that several technical improvements in our ability to model pintail harvest dynamics be considered. In addition, we undertook an effort to evaluate pintail harvest potential based on these model improvements and to explore the impacts of these improvements on past and future pintail harvest management policy. Notable findings from this report, especially those that might warrant comment, are summarized below.

- *Breeding Population Survey Corrections.* There is general agreement among waterfowl scientists that the May breeding population survey undercounts pintails in dry years when pintails tend to settle farther north on the breeding grounds. We developed a method to correct the observed breeding population estimates for this bias. The effect of this correction is to remove some of the apparent sharp drops in pintail numbers during dry years. Further, this correction suggests that in recent years, there are 30-60% more pintails in the breeding population than the May surveys indicate.
- *Updated Recruitment, Harvest, and Population Models.* We developed improved methods to predict recruitment and harvest, and included these components in an updated population model for use in the pintail harvest strategy. The recruitment model uses latitude of the pintail population and the corrected breeding population size estimates as predictors. The harvest models identify a "season-within-a-season" effect in the Central and Mississippi flyways. The new population model predicts population change better than the previous model.
- *Pintail Harvest Potential.* Using the new pintail population model, we were able to analyze the harvest potential of the pintail population. There is evidence that the pintail population is settling, on average, about 2.4° of latitude farther north now than it did prior to 1975, possibly as a result of changes in habitat. This more northern distribution has resulted in lower reproduction, a 30-45% decrease in carrying capacity, and a 40-65% decrease in sustainable harvest potential.
- *Pintail Harvest Strategy.* If we embed these technical improvements into the current pintail harvest strategy, and take account of the post-1975 environmental conditions, we expect pintail season length to deviate from the AHM season length 13% of the time, the average observed pintail BPOP to be around 3.7 million, and the average annual continental harvest to be around 380,000. The frequency of pintail seasons-within-a-season would increase if the North American goal were removed from the AHM objective function.

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## 2. Introduction

North American northern pintails (*Anas acuta*) have shown a substantial population decline in the past 30 years, presumably due to anthropogenic changes to the landscape on the breeding grounds (Miller and Duncan 1999). Prior to this reduction in population size, pintails were an important component of the U.S. harvest, and there continues to be substantial interest in maintaining sustainable harvest of pintails.

In recognition of the poor status of pintails, in 1997 the USFWS developed a special harvest strategy (referred to as the "Interim Pintail Harvest Strategy") that has remained in effect since then. The interim strategy underwent some minor technical changes in 2002 when the harvest models were updated. In the 2002-3 and 2003-4 hunting seasons, the Service set pintail regulations ("season-within-a-season") that deviated from the strict prescriptions of the interim strategy, but remained true to the intent of the strategy. For the 2004-5 hunting season, the Service formally incorporated seasons-within-a-season as a component of the pintail strategy. In adopting those changes, the Service and others called for an analysis of the expected performance of the pintail strategy and consideration of technical modifications that could be made to improve it.

This report contains a thorough review of the demographic and harvest information available at the continental scale for northern pintails. In addition, it considers a number of technical modifications that might be made to the modeling framework used in the pintail harvest strategy. Finally, it begins to explore the harvest implications of the current pintail strategy, especially with regard to the impact of the long-term changes to the breeding habitat.

This report is currently undergoing formal peer-review through the US Geological Survey. We are releasing this draft prior to the completion of peer review so the Flyway technical committees have time to review it before their July 2005 meetings. We would welcome feedback from the technical committees, their individual members, or other interested parties. A final version of this report will be prepared in response to all comments received by 1 September 2005, including those that arise from the peer review process. We anticipate distribution of the final version of this report in fall 2005.

## 3. Estimates of Demographic and Harvest Parameters

To facilitate the development of technical improvements to the population modeling framework currently used in the Interim Pintail Harvest Strategy, we found it necessary to update several population parameter estimates based on contemporary information available from the banding and harvest survey programs. These analyses were conducted to extend the time series of demographic parameter estimates originally reported by Sheaffer et al. (1999), which included estimates of direct recovery rates, relative harvest vulnerabilities, age ratios, and annual survival and recovery rates. The primary purpose of this work was to update the population age ratio estimates for use in the development of a predictive model of pintail recruitment and to update our current knowledge of pintail annual survival and recovery rates.

*Direct recovery rates and harvest vulnerabilities*. We estimated direct recovery rates of pintails encountered in the United States during the hunting season from 1960 – 2003 (Appendix 2). Direct recovery rates were based on the number of pre-season bandings (July-September) and unsolicited recoveries of individuals shot or found dead during the hunting season (September – January). We calculated direct recovery rates ($f$) and corresponding variances in year $t$ for each sex ($s$) and age class ($a$ = young or adult) according to

$$f_{t,s,a} = m_{t,s,a} / R_{t,s,a} \text{ and} \quad (3.1)$$

$$Var(f_{t,s,a}) = f_{t,s,a}(1 - f_{t,s,a}) / R_{t,s,a}, \quad (3.2)$$

where, $m_{t,s,a}$ = number of direct recoveries of individuals of sex $s$ and age $a$ in year $t$ and $R_{t,s,a}$ = total number of birds of sex $s$ and age $a$ released in year $t$. We used direct recovery rate estimates of birds encountered in the US to calculate the relative vulnerability (young:adult) of pintails to the US harvest (Appendix 3). For each sex ($s$), we estimated the age-related vulnerability and corresponding variances in year $t$ with

$$V_{t,s} = f_{t,s,young} / f_{t,s,adult} \text{ and} \quad (3.3)$$

$$Var(V_{t,s}) = \frac{Var(f_{t,s,young})}{f_{t,s,adult}^2} + \frac{f_{t,s,young}^2 Var(f_{t,s,adult})}{f_{t,s,adult}^4}. \quad (3.4)$$

*Population age ratios*

We used the ratio of young to adult females in the US harvest to calculate pintail population age ratios ($R_{t,female}$) according to

$$R_{t,female} = A_{t,female} / V_{t,female} \text{ (Martin et al. 1979),} \quad (3.5)$$

where $A_{t,female}$ is the female age ratio in the US harvest in year $t$ (Appendix 3).

Estimates of age-related female vulnerability to the US harvest have been variable, ranging from a low of 0.97 in 1982 to a high of 3.46 in 1992 (Figure 3.1 A). The female population age ratio from 1961 to 2003 is also variable (Fig. 3.1 B) with a long term mean equal to 1.01 (se = 0.061).

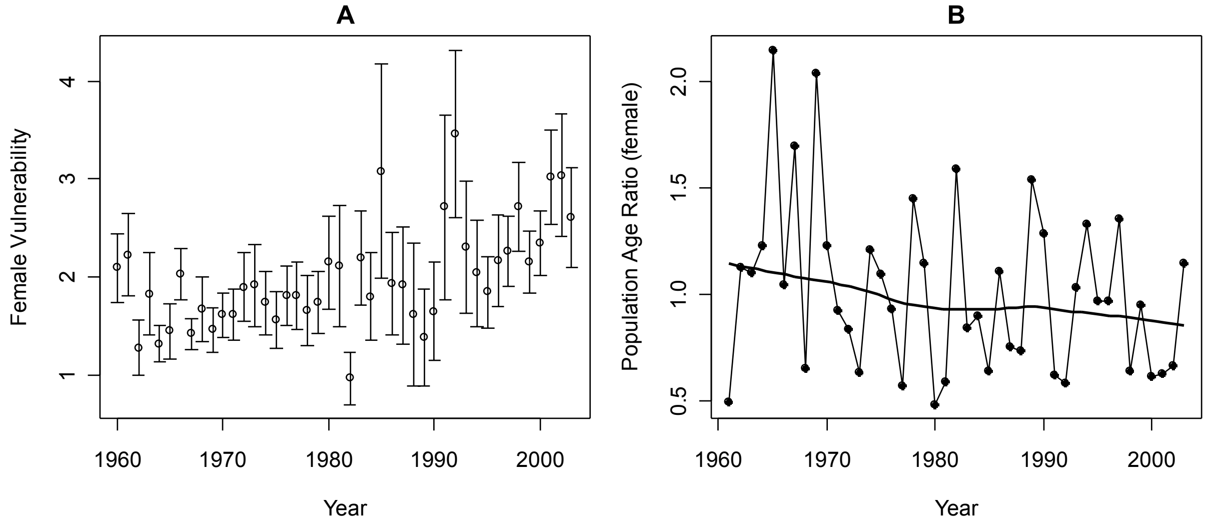


Figure 3.1. A. The relative vulnerability (young:adult) of female pintails to the US harvest from 1961 to 2003; error bars represent plus or minus one standard error. (B) The population age ratio (female) of pintails from 1961 to 2003 calculated from the US harvest age ratio and the female age-related vulnerability estimates. The solid line represents a loess smooth.

*Annual survival and recovery rates*

We calculated annual survival and recovery rates for each sex and age class using Brownie model H1 (Brownie et al. 1979) in program Mark (White and Burnham 1999). We used recoveries of individuals banded preseason in Canada and the United States that were shot or found dead during the hunting season.

Annual survival rates from 1960 to 2002 were highly dynamic across all sex and age classes (Figures 3.2 A1-4). In addition, the estimated confidence intervals were very large, making it hard to evaluate how annual survival of northern pintails has changed over time (Appendices 4-7). The large sampling errors may be attributed to the limitations of the pintail banding and recovery data. In contrast to the annual survival estimates, the recovery rate estimates suggest a common pattern of decreasing recovery rates from the 1970's through the 90's with large increases in recovery rates throughout the period of liberalization associated with the Adaptive Harvest Management program (Figures 3.2 B1-4). Our ability to determine if these changes are representative of actual changes in harvest rates or changes in reporting rates are constrained by the lack of reporting rate information. However, the recovery rate information does depict a common signal across all sex and age classes, including a consistent reduction during the restrictive seasons in 2002 and 2003. This evidence suggests that these estimates may be informative when evaluating how changes in pintail harvest policy may affect pintail recovery rates.

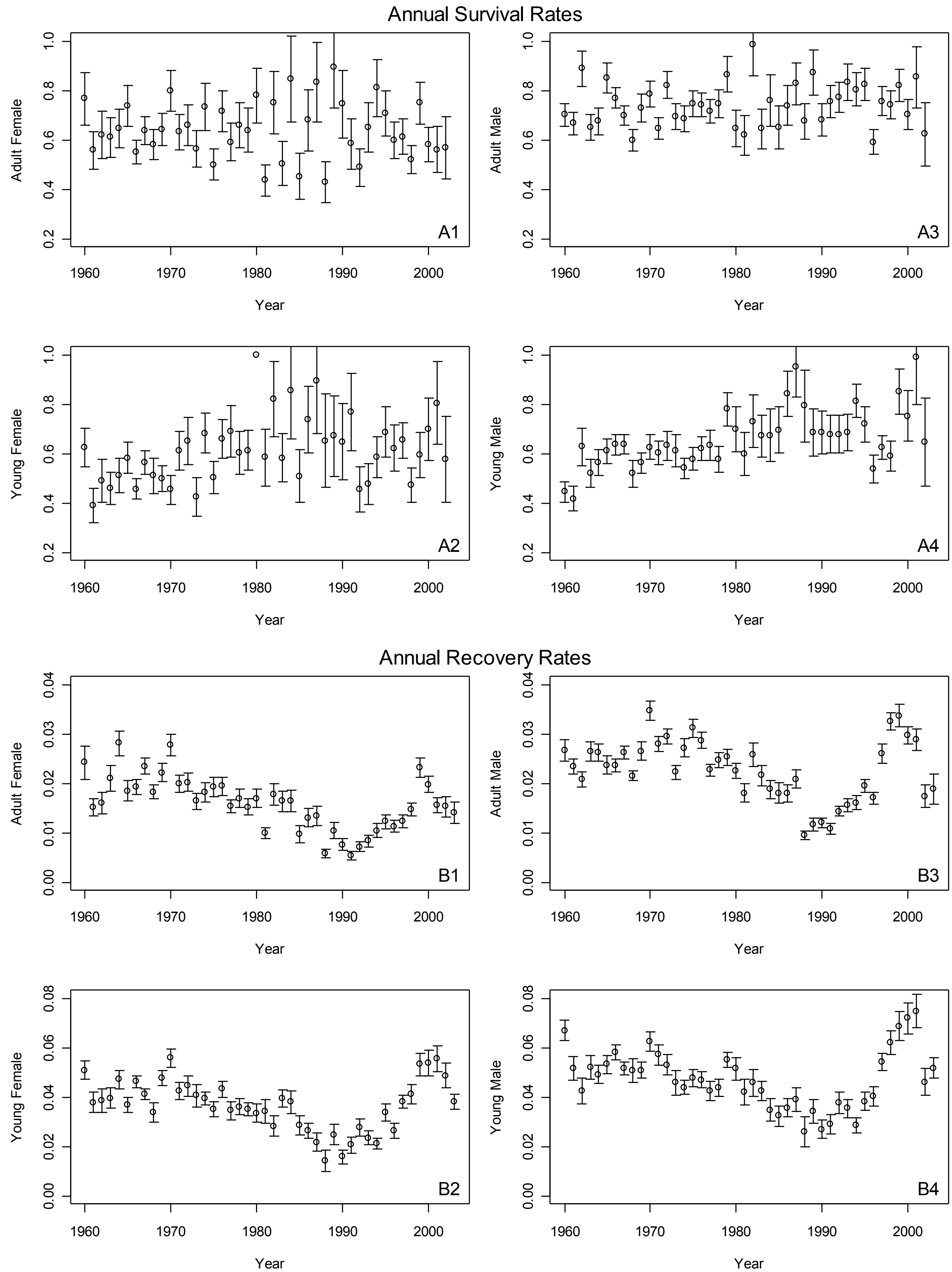


Figure 3.2. Annual survival (A1-4) and recovery rate (B1-4) estimates for adult and young northern pintails banded preseason in the US and Canada and recovered during the hunting season from 1960-2003. Error bars represent plus or minus one standard error.

## 4. Harvest Models

We updated models to predict the total harvest of pintails in each Flyway as a function of Flyway-specific regulations. Our modeling approach was very similar to the analyses used to derive the current harvest models (Runge 2002), but included an additional 3 years of harvest data resulting from seasons specified under the Interim Pintail Harvest Strategy. The additional years of data (2001-2003) also provided experience with regulations that prescribed restrictive seasons (seasons-within-a-season). In addition, our updated analysis accounted for differences in harvest data collection methods associated with the change from the traditional Mail Questionnaire Survey (MQS) to the operational Harvest Information Program (HIP) survey conducted by the Branch of Harvest Surveys. We attempted to model the pintail harvest for each flyway based on a suite of predictors including season length, bag limit, May breeding population estimates, and the mid-winter survey. We used indicator variables to model the effect of a season-within-a-season (SIS) and to represent data collected with the HIP survey protocol. For each flyway-specific analysis, we were unable to detect a significant effect of the HIP survey relative to the MQS.

*Central Flyway.* Based on the previous analysis, we used data from 1985 – 2003 (Appendix 8) to avoid the complication of information collected under the Point System (10-bird bags). There is a significant season-within-a-season effect (SIS) effect ($P = 0.03$), when this variable is included in a model that predicts harvest as a function of the number of days and the bag limit (Table 4.1). We tested additional models that included interaction terms, but did not consider these models based on regression diagnostics.

**Table 4.1.** The results from fitting a linear model that predicts the pintail harvest in the Central Flyway as a function of season length (Days), bag limit (Bag) and a season-within-a-season effect (SIS).

**Central Flyway: Harvest = Days + Bag + SIS**

```
lm(formula = Harvest ~ Days + Bag + SIS, data = cf, subset = 7:28)
Residuals:
   Min     1Q Median     3Q    Max
-28628  -3666  -1668   6135  21721

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)   -95245      11776  -8.088 2.10e-07 ***
Days            2946        180  16.367 2.97e-12 ***
Bag            15228       3359   4.534 0.000257 ***
SIS            23136       9609   2.408 0.026996 *
---
Signif. codes:  '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 12010 on 18 degrees of freedom
Multiple R-Squared: 0.9437,     Adjusted R-squared: 0.9343
F-statistic: 100.6 on 3 and 18 DF,  p-value: 1.952e-11

Analysis of Variance Table
Response: Harvest
          Df     Sum Sq    Mean Sq  F value    Pr(>F)
Days       1 4.0128e+10 4.0128e+10 278.0835 2.164e-12 ***
Bag        1 2.5708e+09 2.5708e+09  17.8153 0.0005139 ***
SIS        1 8.3653e+08 8.3653e+08   5.7971 0.0269961 *
Residuals 18 2.5974e+09 1.4430e+08
AIC 481.3417
```

The resulting model to predict pintail harvest ($H$) in the Central Flyway is:

$$H = -95245.2 + 2946.285\ Days + 15228.03\ Bag + 23136.04\ SIS \qquad (4.1)$$

where *Days* is the season length, *Bag* is the bag limit and *SIS* is an indicator variable with a value equal to 0 (full season) or 1 (season-within-a-season). As a result of the significant SIS effect, the Central Flyway pintail harvest model predicts a larger harvest under a restrictive pintail season within an otherwise liberal duck season than the harvest predicted for a season that is restrictive for all ducks (Fig. 4.1).

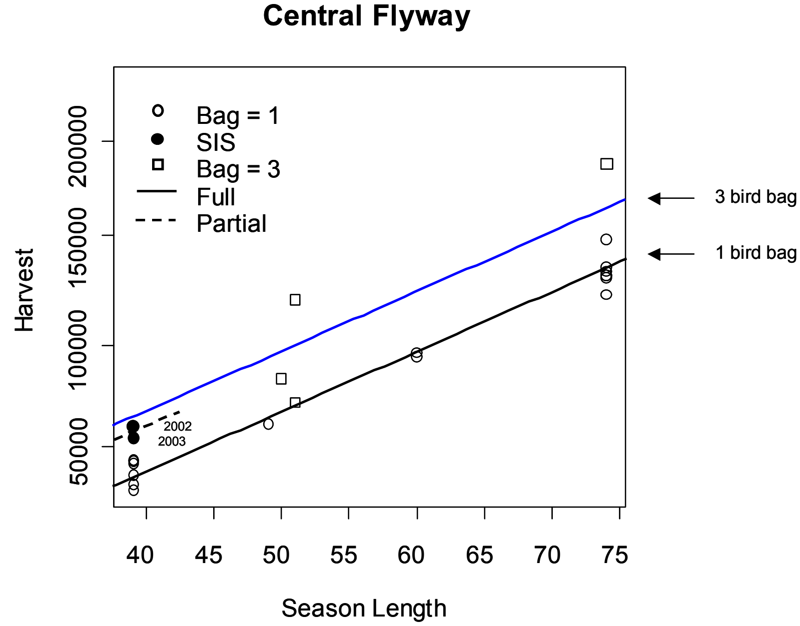


**Fig. 4.1.** Observed Central Flyway harvest (1985-2003) and predicted harvest calculated as a function of season length and bag limit of one (lower solid line) or three (upper solid line) based on the Central flyway harvest model, which includes a season within a season effect. Note, the harvest predicted under a season-within-a-season (dashed lined) assumes a 1-bird bag.

*Atlantic Flyway.* In 2002 and 2003 the Atlantic Flyway adopted a season-within-a-season, and subsequently experienced the largest recorded harvests associated with 30-day seasons and a 1-bird bag since 1979 (Appendix 9). As in the previous analysis (Runge 2002), an initial best subsets regression procedure with all predictor data failed to generate any reasonable models with season length or bag limit as predictors. As a result, we used methods from the previous analysis to reclassify bag limit information into 3 levels (1, 2, >= 3) using the entire data set (1979-2003). In addition, we tested additional models that included interaction terms, but did not consider these models based on regression diagnostics. The resulting model (Table 4.2) predicts harvest ($H$) as a function of season length (*Days*) and a linear effect of the reclassified bag limit (*BagClass*) values with

$$H = -2403.06 + 360.95\ Days + 5494\ BagClass. \qquad (4.2)$$

Predictions from this model are shown in Fig. 4.2.

**Table 4.2.** The results from fitting a linear model that predicts the pintail harvest in the Atlantic Flyway as a function of season length (Days) and bag limit (BagClass) classified to 1, 2, or ≥ 3.

**Atlantic Flyway: Harvest=Days+BagClass LINEAR**

```
lm(formula = Harvest ~ Days + BagClass, data = af, subset = c(1:28))
Residuals:
   Min     1Q Median     3Q    Max
-13490  -3991  -1167   3431  16336

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  -2403.1     5219.3  -0.460  0.64919
Days           360.9      111.1   3.250  0.00329 **
BagClass      5494.0     1516.0   3.624  0.00129 **
---
Signif. codes:  ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 6720 on 25 degrees of freedom
Multiple R-Squared: 0.555,      Adjusted R-squared: 0.5194
F-statistic: 15.59 on 2 and 25 DF,  p-value: 4.025e-05

Analysis of Variance Table
Response: Harvest
          Df     Sum Sq    Mean Sq F value    Pr(>F)
Days       1  814734929  814734929  18.044 0.0002616 ***
BagClass   1  593024945  593024945  13.134 0.0012920 **
Residuals 25 1128828111   45153124
AIC 577.8033
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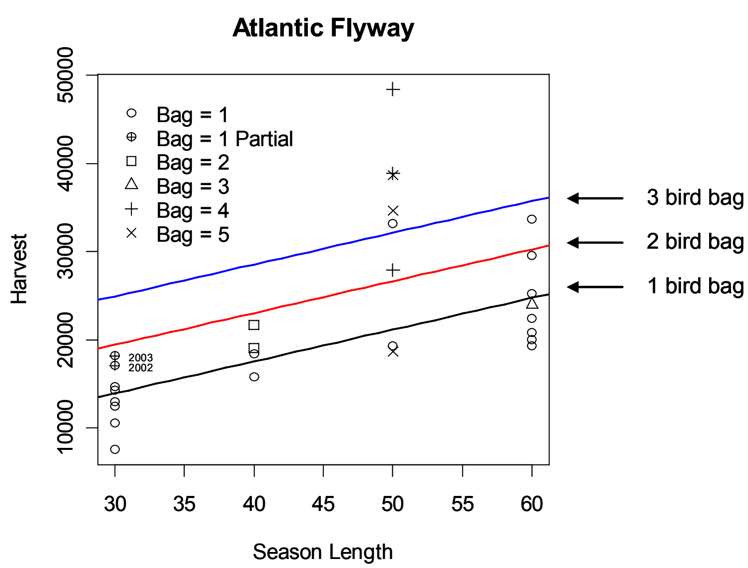


**Fig. 4.2.** Observed Atlantic Flyway pintail harvest (1979-2003) and predicted harvest calculated as a function of season length and a bag limit of one (lower line), two (middle line) or three (upper line) based on the Atlantic flyway harvest model.

*Mississippi Flyway.* Similar to the Atlantic Flyway, in 2002 and 2003 the Mississippi Flyway adopted a season-within-a-season, and subsequently experienced the largest recorded harvests associated with 30-day seasons and a 1-bird bag since 1979 (Appendix 10). As in the original analysis, we did not use information collected during the 10-bird bag limits under the Point

System (1979-1984). Regression diagnostics based on a model that included season length and bag limits as predictors indicated that the data collected in 1997 had a very high influence as measured by Cook's Distance. As a result, we dropped this data point and refit the models. The resulting model included a significant SIS effect ($P < 0.001$, Table 4.3).

**Table 4.3.** The results from fitting a linear model that predicts the pintail harvest in the Mississippi Flyway as a function of season length (Days), bag limit (Bag) and a partial season effect (SIS).

**Mississippi Flyway: Harvest = Days + Bag + SIS**

```
lm(formula = Harvest ~ Days + Bag + SIS, data = mf, subset = c(7:18, 20:28))

Residuals:
   Min     1Q Median     3Q    Max 
-31116 -10842   1402   8262  23728 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)    
(Intercept) -59083.7    15867.2  -3.724 0.001689 ** 
Days          3413.5      284.8  11.986 1.02e-09 ***
Bag           7911.9     4966.9   1.593 0.129595    
SIS          59510.1    12535.7   4.747 0.000187 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 

Residual standard error: 15530 on 17 degrees of freedom
Multiple R-Squared: 0.8945,     Adjusted R-squared: 0.8759 
F-statistic: 48.05 on 3 and 17 DF,  p-value: 1.626e-08 

Analysis of Variance Table
Response: Harvest
          Df     Sum Sq    Mean Sq  F value    Pr(>F)    
Days       1 2.9223e+10 2.9223e+10 121.1105 3.738e-09 ***
Bag        1 1.2393e+08 1.2393e+08   0.5136 0.4833040    
SIS        1 5.4378e+09 5.4378e+09  22.5364 0.0001866 ***
Residuals 17 4.1020e+09 2.4129e+08                       
AIC 470.4898
```

The resulting model to predict pintail harvest ($H$) in the Mississippi Flyway is:

$$H = -59083.66 \ + \ 3413.49 \ Days + \ 7911.95 \ Bag \ + \ 59510.1 \ SIS \qquad (4.3)$$

where *Days* is the season length, *bag* is the bag limit, and *SIS* is an indicator variable with a value equal to 0 (full season) or 1 (season-within-a-season). As a result of the significant SIS effect, the Mississippi Flyway pintail harvest model predicts a larger harvest under a restrictive pintail season within an otherwise liberal duck season than the harvest predicted for a season that is restrictive for all ducks (Fig. 4.3).

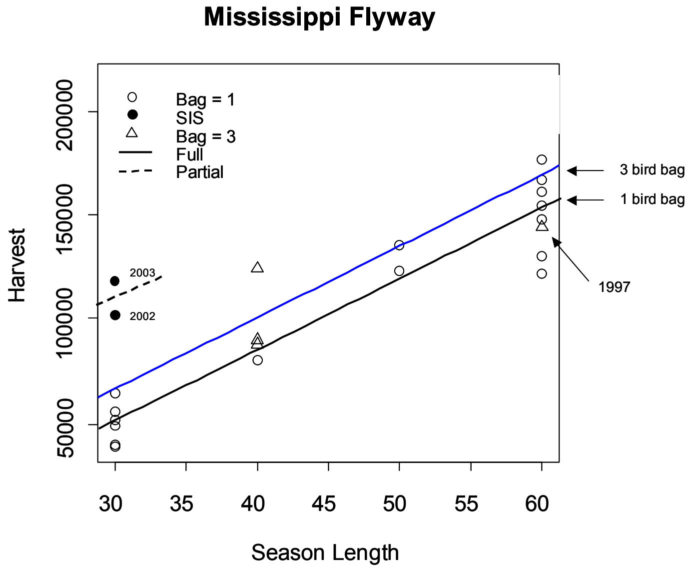


**Fig. 4.3.** Observed Mississippi Flyway harvest (1985-2003) and predicted harvest calculated as a function of season length and bag limit of one (lower solid line) or three (upper solid line) based on the Mississippi flyway harvest model, which includes a season within a season effect. Note, the harvest predicted under a partial season (dashed line) assumes a 1-bird bag.

*Pacific Flyway.* As in the original analysis (Runge 2002), we did not use information collected during the 7-bird bag limits in use from 1979-1983. Based on data from 1984-2003, there is only one year of experience with a 3-bird bag, two years with a 4-bird bag (both at the same season length), and two years with a 5-bird bag (but at different season lengths). The 5-bird bag data provides a little more information about the effect of season length at the higher bag limits. It is visually evident in Fig. 4.4 that there isn't a significant difference between 3, 4 or 5 in the bag, so we considered lumping those higher bag limits as we did in the Atlantic Flyway analysis. As a result, we reclassified bag limit information into 3 levels (1, 2, ≥ 3). In addition, we tested additional models that included interaction terms, but did not consider these models based on regression diagnostics. There was no evidence of a season-within-a-season effect ($P = 0.87$). The resulting model (Table 4.4) predicts harvest ($H$) as a function of season length (*Days*) and a linear effect of the reclassified bag limit (*BagClass*) values with

$$H = -12051.41 + 1160.96\, Days + 73911.49\, BagClass . \quad (4.4)$$

Predictions with this model are shown in Fig. 4.4.

**Table 4.4.** The results from fitting a linear model that predicts the pintail harvest in the Pacific Flyway as a function of season length (Days) and bag limit (BagClass) classified to 1, 2, or ≥ 3.

**Pacific Flyway: Harvest=Days+BagClass LINEAR**

```
lm(formula = Harvest ~ Days + BagClass, data = pf, subset = 6:28)

Residuals:
   Min      1Q Median     3Q    Max
-52775 -11367   2798   9579  51194

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) -12051.4    22479.9  -0.536 0.597803
Days          1161.0      254.8   4.556 0.000192 ***
BagClass     73911.5     6313.7  11.707 2.10e-10 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 24740 on 20 degrees of freedom
Multiple R-Squared: 0.8994,     Adjusted R-squared: 0.8893
F-statistic:  89.4 on 2 and 20 DF,  p-value: 1.062e-10

Analysis of Variance Table
Response: Harvest
          Df     Sum Sq    Mean Sq F value    Pr(>F)
Days       1 2.5566e+10 2.5566e+10  41.767 2.659e-06 ***
BagClass   1 8.3887e+10 8.3887e+10 137.043 2.103e-10 ***
Residuals 20 1.2242e+10 6.1212e+08
AIC 535.4028
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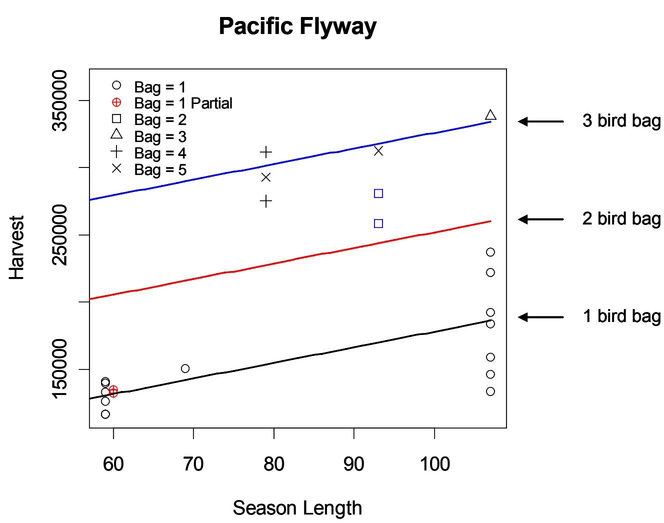



**Fig. 4.4.** Observed Pacific Flyway pintail harvest (1984-2003) and predicted harvest calculated as a function of season length and a bag limit of one (lower line), two (middle line) or three (upper line) based on the Pacific flyway harvest model.

*Total Harvest Predictions.* The updated harvest models provide a predictive relationship between flyway-specific hunting regulations and the expected harvest of pintails. The population model used under the current Interim Pintail Harvest Strategy assumes that the annual harvest from Alaska and Canada is a fixed value equal to 67,000 birds, based on modifications made in February 2002 (for comparison, the average harvest in Alaska and Canada from 1996 through 2003 was 65,910, see Appendix 12). We used this fixed harvest amount (67,000) for Alaska and Canada and the updated harvest models to predict the total continental pintail harvest expected under a range of different regulatory options (Table 4.5). These results indicate a larger expected harvest under a season-within-a-season as compared to the expected harvest under an overall restrictive framework for all duck species. Caution is also warranted when evaluating the predictions under a liberal season with a two-bird bag because we have very little experience with these regulations.

**Table 4.5.** Predicted harvest of pintails calculated with the updated Flyway-specific harvest models, as a function of different regulatory options.

| | Harvest Regulation[1] | | | | |
|---|---|---|---|---|---|
| **Flyway** | **R1** | **R1SIS** | **L1** | **L2** | **L3** |
| Central | 34,877 | 58,013 | 137,987 | 153,215 | 168,443 |
| Atlantic | 13,918 | 13,918 | 24,745 | 30,239 | 35,733 |
| Mississippi | 51,233 | 110,743 | 153,638 | 161,550 | 169,462 |
| Pacific | 131,520 | 131,520 | 186,087 | 259,999 | 333,910 |
| **Total US** | **231,548** | **314,194** | **502,457** | **605,003** | **707,548** |
| Alaska/Canada | 67,000 | 67,000 | 67,000 | 67,000 | 67,000 |
| **Total** | **298,548** | **381,194** | **569,457** | **672,003** | **774,548** |

[1] **R1** = Restrictive season with a one bird bag.
**R1SIS** = Restrictive season within an overall liberal framework (season-within-a-season) with a 1 bird bag.
**L1** = Liberal season with a 1-bird bag.
**L2** = Liberal season with a 2-bird bag.
**L3** = Liberal season with a 3-bird bag.

## 5. Accounting for Overflight Bias

One of the major concerns with the current pintail harvest policy is that it relies on population size estimates from the May aerial survey that are biased. In dry years on the prairie when pintails settle farther north, the BPOP tends to drop at a rate that cannot be explained by population dynamics alone. There is a notable negative relationship between BPOP estimates and latitude (Fig. 5.1a), suggesting that BPOP is lower when latitude is higher. This relationship could be explained by at least two hypotheses: (i) the overflight hypothesis—when pintails settle farther north, a smaller proportion are counted, thus the population estimate is lower; or (ii) the recruitment hypothesis—when pintails settle farther north, the continental production is lower, and because dry periods tend to last several years, this eventually results in lower population sizes, thus inducing the negative correlation observed. We can distinguish these two hypotheses by detrending the BPOP and latitude time series, that is, by looking at the one-year changes in BPOP and latitude against each other (Fig. 5.1b). Since the recruitment hypothesis would produce the negative relationship in Fig. 5.1a through a time-delayed mechanism, if that hypothesis holds, the detrended series should not exhibit the negative correlation. The detrended series (Fig. 5.1b) show that all other things being equal, when the latitude increases between year $t$–1 to year $t$, the BPOP estimate drops, supporting the overflight hypothesis.

The relationship between the detrended BPOP and latitude series suggests a method to correct the BPOP estimates for this overflight bias. The line fit through the detrended series has a significant slope of –0.0741; for every 1 degree increase in latitude, the logarithm of the BPOP estimate drops by 0.0741 (this is equivalent to a 7.1% decrease). Mathematically,

$$\Delta \ln B_t = -0.0741 \Delta L_t \tag{5.1}$$

where $B_t$ is the breeding population size estimate in year $t$, and $L_t$ is the latitude of the center of the distribution of the breeding population in year $t$. Equation 5.1 can be expanded to

$$\ln B_t - \ln B_{t-1} = -0.0741(L_t - L_{t-1}). \tag{5.2}$$

This equation (5.2) could be used to correct a BPOP in one year to put it on the same scale as the BPOP in the previous year (by "same scale", we mean relative to the latitude). By extension, we could modify this equation to express this year's BPOP relative to some other scale. We'd like to express it on the "true" scale, but there is no point that we know is completely unbiased in estimating the pintail population size. As an approximation, we chose 1969, the year in which the latitude of the pintail population was as far south as it has ever been observed (51.68°N). Thus, we can modify equation 5.2 to

$$\begin{aligned} \ln B_{obs} - \ln B_{"true"} &= -0.0741(L_{obs} - L_{"true"}) \\ \ln B_{obs} - \ln B_{"true"} &= -0.0741(L_{obs} - 51.68) \end{aligned} \tag{5.3}$$

and then a little algebra allows us to develop an expression for the corrected BPOP estimate:

$$\begin{aligned} \ln B_{"true"} &= \ln B_t + 0.0741(L_{obs} - 51.68) \\ B_{"true"} &= e^{\ln B_t + 0.0741(L_{obs} - 51.68)} \end{aligned} . \tag{5.4}$$

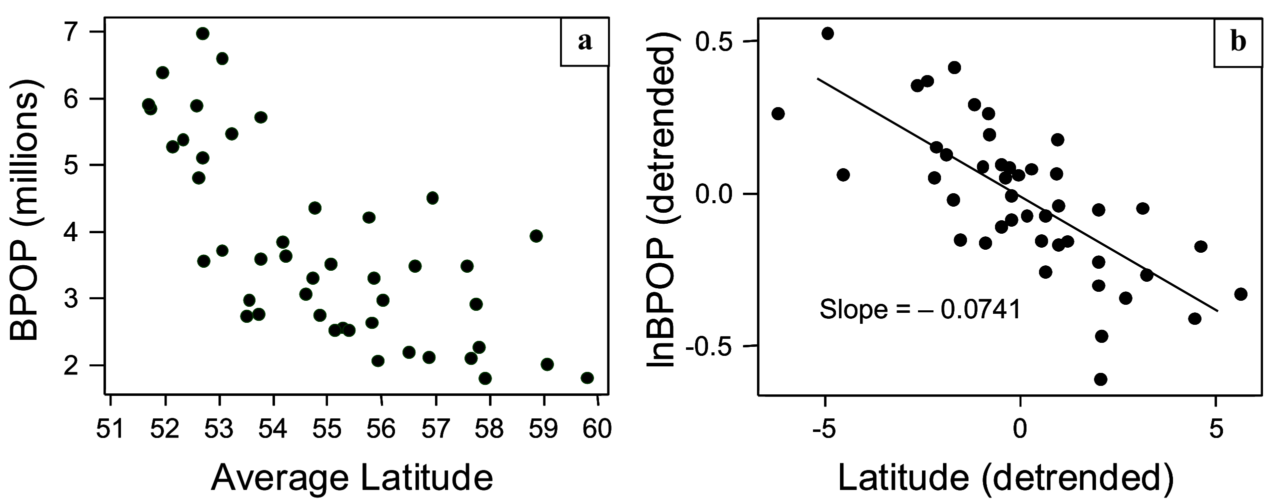



**Fig. 5.1.** Observed pintail breeding population size plotted against the latitude of the center of the distribution of the pintail population, 1960-2004. (a) Observed values. (b) Detrended values. The logarithm of the ratio of the breeding population size in year $t$ to the population size in year $t$–1 is plotted against the difference in latitude between year $t$ and year $t$–1. The fitted line has a slope of –0.0741.

The problems of overflight bias can be seen in the graph of observed breeding population size estimates against time (Fig. 5.2, solid line): there are years (e.g., 1968, 1973, and 1977) when a large portion of the pintail population seems to disappear, only to reappear a year later; and the decline between 1975 and 1990 was accompanied by an increase in latitude, raising the question of whether the apparent decline was exaggerated by an increasing trend in overflight. The corrected estimates of the breeding population size (Fig. 5.2, dotted line) largely remove these patterns. In recent years, the correction suggests there are 30-60% more pintails in the breeding population than the May surveys indicate (see corrected values in Appendix 1).

This correction to the aerial survey dovetails with the findings from the satellite telemetry project of Miller et al. (2003), who state that the "May Survey did not efficiently account for pintails." One hypothesis for the overflight bias is a detectability issue in the northern strata. In the prairie strata, the May aerial survey, with coordinated annual ground counts, estimates the pintail population relatively accurately. But in the northern strata, perhaps the aerial survey estimates miss a substantial portion of the population. Potential reasons for this include: the visibility adjustment factors are not estimated regularly and might be biased; the strata may not be located in all the areas pintails use; the timing of surveys may not be optimized for pintail migration; and the area expansion factors for some of the northern strata may be too small. Whatever the reason, if the estimates from the southern strata are largely unbiased and the estimates from the northern strata are negatively biased, then the degree of overall bias depends on the distribution of the pintail population among northern and southern strata, a distribution that is captured to a large degree by the latitude of the breeding population. This hypothesis underlies our choice of 1969 as the reference point in the correction; because that was the year with the southernmost observed pintail distribution, the correction in all other years produces estimates that are higher than the observed survey estimates.

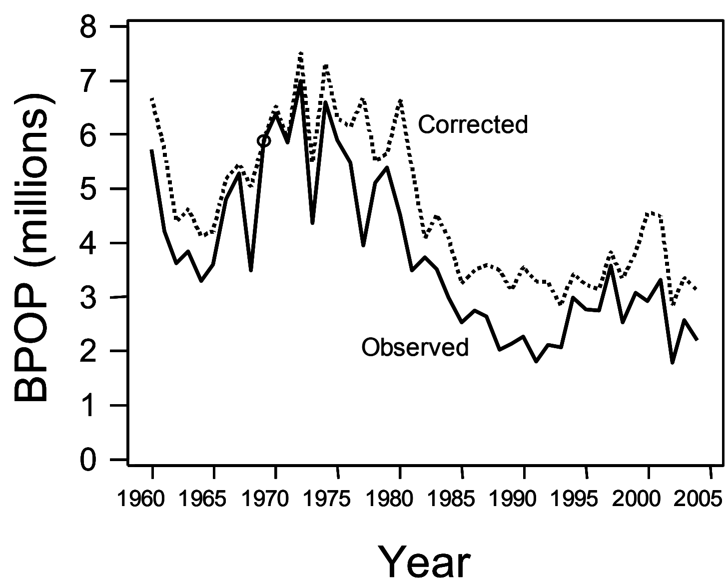



**Fig. 5.2.** Observed and corrected pintail breeding population sizes, 1960-2004. The correction is based on the average latitude of the breeding population, and is calibrated so the two curves coincide in 1969 (the year with the most southern observed latitude).

The derived correction (equation 5.4) is an attempt to empirically remove this overflight bias. Use of this correction is supported in several ways: (i) the correction is based on a statistical relationship that supports the overflight hypothesis; (ii) the corrected BPOP estimates are intuitively appealing, because to a large degree they remove the disturbing patterns in the time series of observed BPOP estimates; and (iii) use of these corrected BPOPs in a pintail population model significantly improves our ability to predict changes in the population size (see section 8.1, "Predictive Ability of Population Models", below). Use of this correction could be questioned for at least two reasons: it involves an arbitrary choice of reference point; and it is an empirical, rather than mechanistic, correction. We believe it is important for the US Fish and Wildlife Service and the Flyways to evaluate this correction and determine whether the corrected breeding population size estimates should be the basis of decision-making, especially in relation to harvest management.

## 6. Recruitment Models

The recruitment model currently used in the pintail harvest strategy was developed in 1997. There are three important reasons to consider updating it at this time. First, there is additional data (7 years worth) to include in a new analysis. Second, we now recognize that the current recruitment model is not explicitly density-dependent, but is implicitly so because one of the predictors in the model is strongly correlated with pintail BPOP. Third, with the development of the overflight-bias correction, we have a new predictor to consider including.

The recruitment model currently in use predicts the vulnerability-adjusted age-ratio (the fall age-ratio) as a function of the latitude of the center of the breeding population distribution, the variance of that mean latitude, and the ratio of the population size in northern vs. southern strata. The current model is

$$\ln R_t = 7.4076 - 0.1372 L_t + 0.033 P_{32} Var\left(L_t\right) \quad (6.1)$$

where $R_t$ is the female population age-ratio (see section 3 above), $L_t$ is the latitude of the center of the pintail distribution, and $P_{32}$ is the ratio of pintails in northern to southern strata. The variance of the latitude is not a measure of the latitudinal spread of the pintail population, but a measure of sampling error in estimating $L_t$; thus, it is inversely proportional to the sample size, that is, the pintail population size. In this way, the variance term is actually density-dependent, and induces density-dependence in the recruitment model. For the purposes of analysis, however, it is much easier to have the density-dependence be explicit, rather than hidden in one of the other variables.

We used the analysis of Sheaffer et al. (1999) as the basis for developing a new recruitment model. After extensive consideration of many predictors, they found that latitude and pintail BPOP were the most important predictors of recruitment, with some additional explanatory power provided by a few other environmental variables. We substituted the latitude-corrected pintail BPOP (see section 5 above) for the observed pintail BPOP, after analysis showed that it was a better predictor. The modified recruitment model is

$$\ln R_t = 7.605 - 0.1318 L_t - 0.0921 B_t^{adj} \quad (6.2)$$

where $B_t^{adj}$ is the latitude-adjusted breeding population size (from equation 5.4). Both the latitude and the BPOP effects are highly significant ($P$<0.001 and $P$ = 0.014, respectively). This model explains 48.5% of the variation in the observed recruitment data (1961-2003), approximately the same amount explained by the model currently in use (equation 6.1). That is, in any given year, the predictions from these two models are very similar, but the new model has a clear mechanistic explanation and is more amenable to the types of analyses we commonly employ with duck population models. Regression diagnostics did not reveal any violations of the assumptions of the linear model. In particular, it's important to note there was no evidence that the effects of latitude or population size on recruitment had changed over time.

To explore uncertainty in this recruitment relationship, we considered parameter values on the 80% confidence ellipsoid, found using

$$\left(\beta-\hat{\mathbf{b}}\right)'\mathbf{X}'\mathbf{X}\left(\beta-\hat{\mathbf{b}}\right)\leq ps^2F_{p,n-p,0.80} \tag{6.3}$$

where $\beta$ is the vector of parameter estimates on the 80% confidence ellipsoid, $\hat{\mathbf{b}}$ is the vector of maximum likelihood estimates for the parameters, $\mathbf{X}$ is the design matrix for the linear model, $p$ is the number of parameters, $s^2$ is the mean squared error from the regression, and $F$ refers the the $F$-statistic with $p$ and $n–p$ degrees of freedom (Draper and Smith 1981). Five alternative models were considered (Table 6.1); their implications for the estimation of carrying capacity are discussed later in this report. There are an infinite number of parameter combinations on the 80% confidence ellipsoid; we chose these 4 (models 1-4) to emphasize uncertainty in the latitude effect.

**Table 6.1.** Alternative recruitment models used to capture parametric uncertainty in the effects of density and latitude.

| Model | Intercept | Latitude slope | Density Slope | Location |
|---|---|---|---|---|
| 0 | 7.6048 | –0.1318 | –0.0921 | MLE |
| 1 | 5.4693 | –0.0919 | –0.1052 | 80% CE |
| 2 | 9.7407 | –0.1718 | –0.0791 | 80% CE |
| 3 | 4.8636 | –0.0845 | –0.0615 | 80% CE |
| 4 | 10.3455 | –0.1792 | –0.1227 | 80% CE |

## 7. Evidence of Landscape Changes

In the last decade or so, there has been considerable attention focused on understanding the historic decline in pintail numbers and the failure of the pintail population to recover in the late 1990s when record water levels occurred in the Canadian prairies. There is emerging consensus among pintail biologists that the problem is localized to the breeding grounds (Miller and Duncan 1999, Miller et al. 2003). Since the 1950s, there has been a steady conversion of grasslands to cultivation in the western Canadian prairie pothole region, a trend that has reduced the availability of secure upland nesting habitat. The exact demographic mechanism that has driven the change in pintail dynamics remains open for discussion, but several strong hypotheses

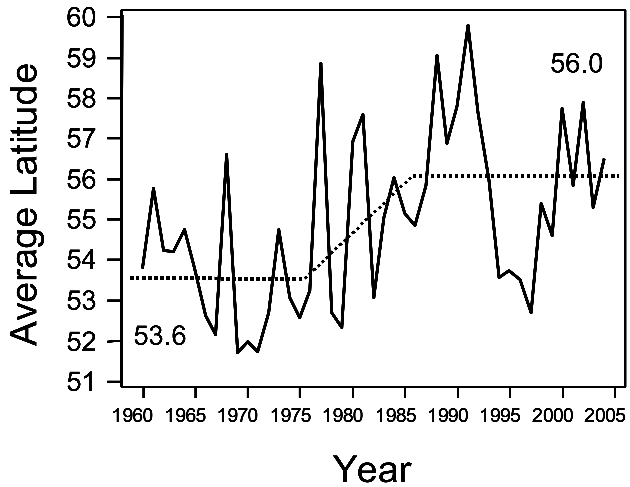



**Fig. 7.1.** Latitude of the center of the pintail distribution, 1960-2004. There is evidence that the average latitude shifted northward by 2.4 degrees between 1975 and 1985.

have been advanced, most of which involve long-term reductions in recruitment brought about by landscape change.

There is suggestive evidence on the continental scale that pintails have exhibited a behavioral response to the landscape changes. The distribution of the pintail breeding population appears to have shifted northward by about 2.4° latitude. Prior to 1975, the average latitude of the center of the pintail breeding distribution (as measured by the May surveys) was 53.6°N (with a standard deviation of 1.49 and non-significant autocorrelation of $\rho = 0.01$). Since 1985, that average has been 56.0°N with an increased variance (SD = 1.93) and evidence of stronger autocorrelation ($\rho = 0.51$, $P = 0.02$) (Fig. 7.1). In 1996-7, when water returned to the prairies, pintails did distribute farther south, but not as far south as in the early 1970s. Possibly, pintails are responding to the landscape changes by choosing to overfly the prairies to a greater degree than in the past, even under similar water conditions. An alternate hypothesis is that the component of the population that has the highest fidelity to prairie nesting areas has decreased, while the northern breeding component has remained stable; the net effect is a northward shift in average latitude.

Whatever the reason for the shift in latitude, the implication relative to recruitment is the same: recruitment in the average year, under similar densities and water conditions, has decreased. The best recruitment model (see section 6 “Recruitment Models”) shows a negative effect of latitude: when the latitude in a particular year increases, recruitment decreases, all other things being equal. Thus, this increase in average latitude implies a decrease in average recruitment. The ramifications of this shift on population dynamics and harvest potential are explored below (section 8.2 “Harvest Yield Analysis”).

The preceding argument implies a change in the relationship between pintail distribution and prairie water. The number of ponds in Canada counted during the May aerial surveys is often used as a measure of water on the prairie breeding grounds, and is a central state variable in the determination of harvest regulations for mid-continent mallards. While pintails are often associated with more ephemeral water bodies than those measured by “Canadian Ponds,” there is nevertheless an indication that pintails are settling at higher latitudes relative to the number of

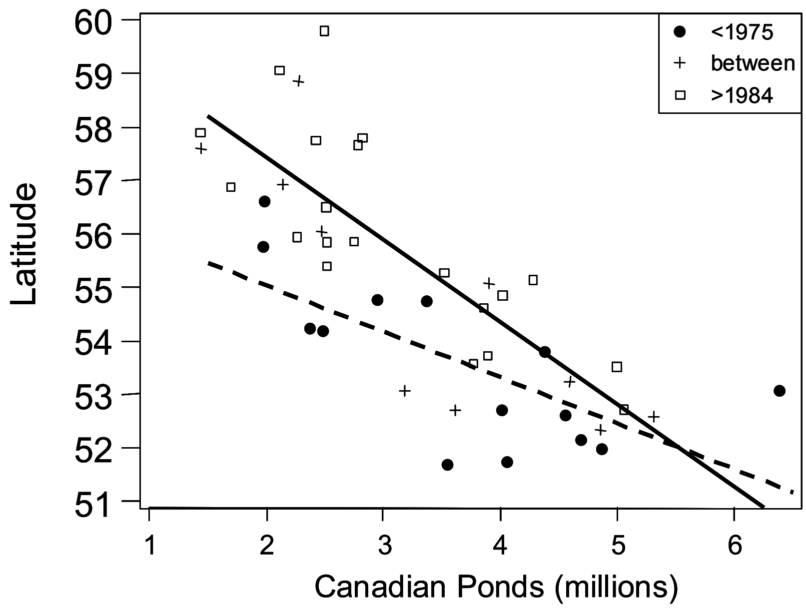



**Fig 7.2.** Latitude of the center of the pintail distribution against Canadian Ponds, 1961-2004. The fitted regression lines correspond to the periods 1961-1974 (dashed line) and 1975-2004 (solid line).

ponds than they were in the past (Fig. 7.2). We explored a large number of linear models fit to these data; the best fit was obtained using a model that distinguished the time period before 1975 from the time period including and after 1975. Prior to 1975, pintail distribution (as measured by average latitude of the breeding population) could be predicted from Canadian Ponds with

$$L_t = 56.7287 - 0.8567 P_t \tag{7.1}$$

and the distribution after 1974 could be predicted with

$$L_t = 60.5474 - 1.5516 P_t \tag{7.2}$$

where $L_t$ is the latitude of the pintail population in year $t$ and $P_t$ is the number of Canadian Ponds. For both equations, the prediction variance is $(1.512)^2$.

There is not evidence that the mean number of Canadian ponds differed before and after 1975 (Table 7.1). Further, as noted in section 6, there is not evidence that the effect of pintail latitude on recruitment differed before and after 1975 (i.e., there is no latitude*time interaction in the regression in equation 6.2). Thus, the reduction in recruitment appears to be driven by a shift in the average latitude.

**Table 7.1.** Descriptive statistics for Canadian Ponds and pintail latitude, 1961-2004. The mean, standard deviation, and first-order autoregressive coefficient (ρ) are shown for three time periods.

| | Canadian Ponds | | | Latitude | | |
|---|---|---|---|---|---|---|
| | **Mean** | **Std** | **ρ** | **Mean** | **Std** | **ρ** |
| 1961-1974 | 3.688 † | 1.267 | 0.2044 | 53.569 ‡ | 1.549 | –0.0063 |
| 1975-2004 | 3.186 † | 1.112 | 0.2478 | 55.605 ‡ | 2.124 | 0.2683 |
| All years | 3.346 | 1.172 | 0.3182 | 54.957 | 2.165 | 0.3915 |

† Mean ponds do not differ significantly between these time periods ($P = 0.22$).
‡ Mean latitude *does* differ significantly between these time periods ($P = 0.001$).

## 8. Population Model

The operational population model that has formed the basis for the Interim Pintail Harvest Strategy is

$$\hat{B}_{t+1}^{obs} = \left[ s_s B_t^{obs} \left( 1 + \gamma_R \hat{R}_t^{old} \right) - \hat{H}_t^{old} / (1 - c) \right] s_w \tag{8.1}$$

where $B_t^{obs}$ is the observed pintail breeding population size in year $t$, $s_s$ and $s_w$ are the summer and winter survival rates, respectively, $\gamma_R$ is a bias-correction constant for the age-ratio, $c$ is the crippling loss rate, and $\hat{R}_t$ and $\hat{H}_t$ are the predicted age-ratio and continental harvest based on the "old" models. Discussion of the recruitment and harvest models is found in preceding sections. The population model in the interim pintail harvest strategy uses the following constants: $s_s = 0.7$, $s_w = 0.93$, $\gamma_R = 0.8$, and $c = 0.2$.

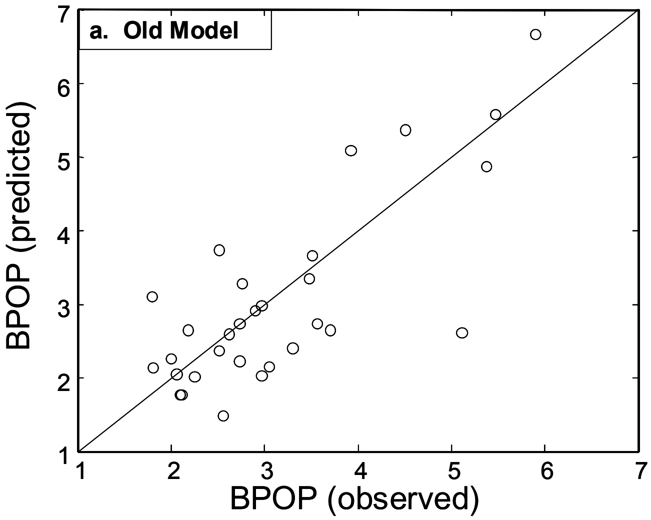
We made three changes to this population model to incorporate analyses detailed in earlier sections: (1) we based the model on the latitude-corrected population sizes (equation 5.4) rather than the observed population sizes; (2) we used the new recruitment model (equation 6.2), which is explicitly density-dependent; and (3) we used the new harvest models (equations 4.1-4.4). Thus, the modified population model is

$$\hat{B}_{t+1}^{adj} = \left[ s_s B_t^{adj} \left( 1 + \gamma_R \hat{R}_t^{new} \right) - \hat{H}_t^{new} / (1 - c) \right] s_w \tag{8.2}$$

where $B_t^{adj}$ is the latitude-adjusted pintail breeding population size in year $t$, $\hat{R}_t$ and $\hat{H}_t$ are based on the new models, and all the constants have the same values as previously. Expanding this equation to incorporate the new recruitment model,

$$\hat{B}_{t+1}^{adj} = \left[ s_s B_t^{adj} \left( 1 + \gamma_R e^{b_0 - b_1 B_t^{adj} - b_2 L_t} \right) - \hat{H}_t^{new} / (1 - c) \right] s_w \tag{8.3}$$

it becomes clear that this population model is explicitly density-dependent, and contains a term (the latitude of the breeding population, $L_t$) that governs environmental effects on the population dynamics.



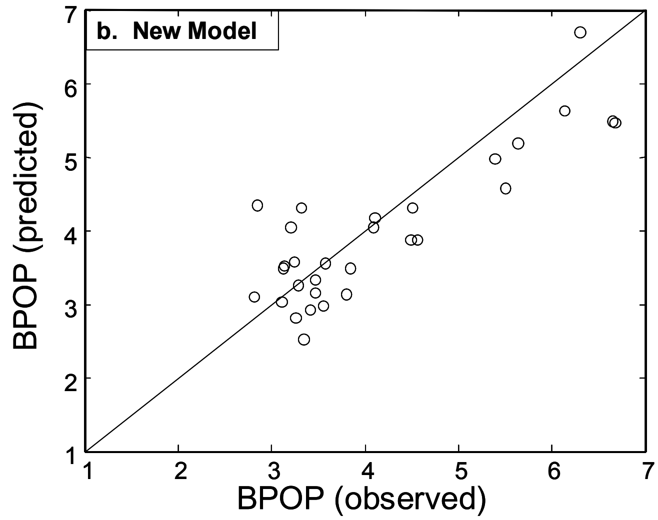




**Fig. 8.1.** Predictive ability of old and new pintail population models, 1974-2004. (a) Old model. Observed and predicted values on the *observed* BPOP scale, in millions. (b) New model. Values on the *corrected* BPOP scale.

### *8.1. Predictive Ability of Population Models*

We were interested in evaluating the performance of the updated population model compared to the current model used in the Interim Pintail Harvest Strategy, and to other candidate predictors of pintail population size. To evaluate the predictive ability of the original and modified population models, we compared the predictions of the next year's BPOP from each model to the observed BPOP values (Fig. 8.1). In a perfect model, the predictions will be equal to the observed values (that is, they'll fall on the $y = x$ line in the graphs shown). Both models appear to be unbiased in their predictions, because there is no evident directional departure from the expected values. The predictions from the original ("old") model show greater variance from the observed values than the predictions from the modified ("new") model, indicating that the modified model is a more precise predictor than the old model.

To quantify the differences in predictive ability, we calculated the sums of squared error between the predictions and the observed values. In order to make a direct comparison between the two models, the predictions needed to be made on the same scale, so we converted the corrected BPOP estimates from the new model to the original scale, using the inverse of the overflight correction (the inverse of equation 5.4). We also considered a number of other predictors for next year's BPOP ($B_{t+1}$), including the observed BPOP in year $t$ (model 2) and the observed BPOP in year $t$ corrected for the change in latitude between $t$ and $t$+1 (model 3). For the old and new models, we considered the predictions using the recruitment model, and predictions using the observed age-ratios instead. We compared all the sums of squared error to the "total sum of squares," which is the same as thinking of the mean BPOP as the predictor (model 1), and calculated a metric which is like $R^2$, in that it measures the amount of variation explained by the model (Table 8.1).

The most important information for predicting BPOP ($t$+1) is the current year's BPOP—model 2 explains about 63% of the variation. Using the overflight-correction to put BPOP($t$) and BPOP($t$+1) on the same scale increases $R^2$ to 78% (model 3). Because the old model (model 4) does not contain an overflight correction, it performs worse than the overflight-corrected BPOP($t$), with an $R^2$ of only 48%; in fact, this is worse than simply using the observed BPOP from year $t$. The new model, back-transformed to the observed BPOP scale (model 6), was the best predictor, and explained 83% of the variation in BPOP($t$+1). Interestingly, the old and new models both performed better when using their models of recruitment, rather than the actual observed values for recruitment; we have not yet determined why this is the case.

In summary, when the technical modifications are included in the population model, the predictive ability of the model increases greatly (from $R^2$ of 48% to 83%). The vast portion of this improvement is due to use of the overflight-correction.

**Table 8.1.** Precision of various predictors of pintail breeding population size. The "$R^2$" value reflects the proportion of the observed variation captured by the particular predictor, and is calculated as: 1–SSE(model x)/SSE(model 1).

| Predictive Model for observed BPOP (t+1) | SSE | "$R^2$" |
|---|---|---|
| (1) Mean observed BPOP | 37.09 | 0.0% |
| (2) Observed BPOP (t) | 13.82 | 62.7% |
| (3) Observed BPOP (t), adjusted for Lat (t+1) | 8.15 | 78.0% |
| **(4) Old Model, using predicted R** | **19.19** | **48.3%** |
| (5) Old Model, using observed R | 25.65 | 30.8% |
| **(6) New Model, using predicted R** | **6.46** | **82.6%** |
| (7) New Model, using observed R | 10.62 | 71.4% |

### *8.2. Harvest Yield Analysis*

Because the modified population model (equation 8.3) is explicitly density-dependent, its equilibrium harvest dynamics can be readily calculated (Runge and Johnson 2002). We calculated the carrying capacity by finding the equilibrium population size in the absence of harvest. Because the recruitment is a function of the latitude of the breeding population, carrying

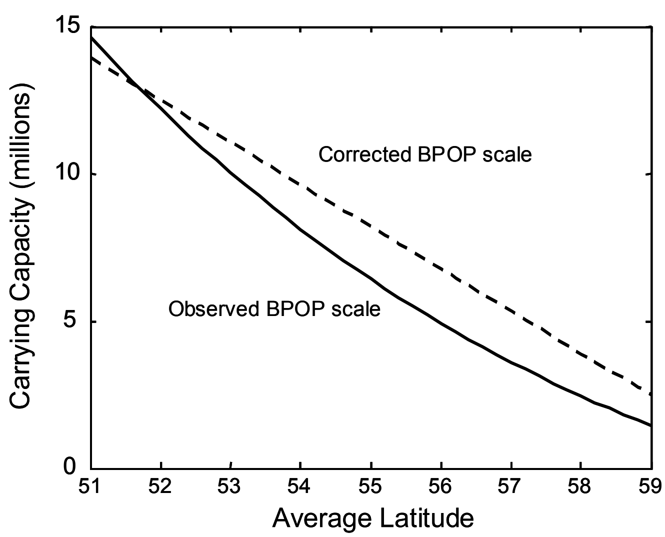



**Fig. 8.2**. Equilibrium population size in the absence of harvest (carrying capacity) as a function of average latitude of the breeding population.

capacity is a function of average latitude (Fig. 8.2). As the average latitude of the pintail distribution moves northward, the continental carrying capacity decreases. With an average latitude of 53.6 (as observed prior to 1975), the carrying capacity is 10.2 million on the latitude-corrected scale (8.9 million on the observed BPOP scale). With an average latitude of 55.6 (as observed since 1975), the carrying capacity is 7.3 million on the latitude-corrected scale (5.5 million on the observed scale). That is, if changes in the landscape have produced the shift in pintail distribution discussed above (section 7), then the carrying capacity (as measured by the equilibrium population size in the absence of harvest) has decreased by 28.5%. On the observed BPOP scale, the overflight bias accentuates this loss of carrying capacity, making it appear to be a 38.5% loss.

Loss of carrying capacity has direct implications for the productive capacity of the population and hence for the harvestable surplus. We investigated these implications by deriving harvest yield curves from the population model. To do this, we varied the harvest rate and calculated the corresponding equilibrium population size and sustainable annual harvest (Fig. 8.3). In each of the four curves in Fig. 8.3, the rightmost point shows the equilibrium population size in the absence of harvest (the carrying capacity). As harvest rate increases, the curve moves up and to the left, that is, the equilibrium population size decreases and the sustainable annual harvest increases. At some point, the maximum sustainable harvest is reached; beyond this point, increases in harvest rate continue to lower the equilibrium population size, but now, sustainable harvest also decreases. The two upper curves show the sustainable annual harvest as a function of the corresponding equilibrium population size, when the average latitude of the BPOP is 53.6°N (the average prior to 1975): the carrying capacity (equilibrium population size in the absence of harvest) was about 10.2 million (on the corrected scale, dotted line; 8.9 million on the observed scale), the maximum yield occurred when the population was held around 4.4 million (3.8 million on the observed scale), and the maximum sustainable annual harvest was more than what we would expect to achieve with a liberal season and three-bird bag in all Flyways.

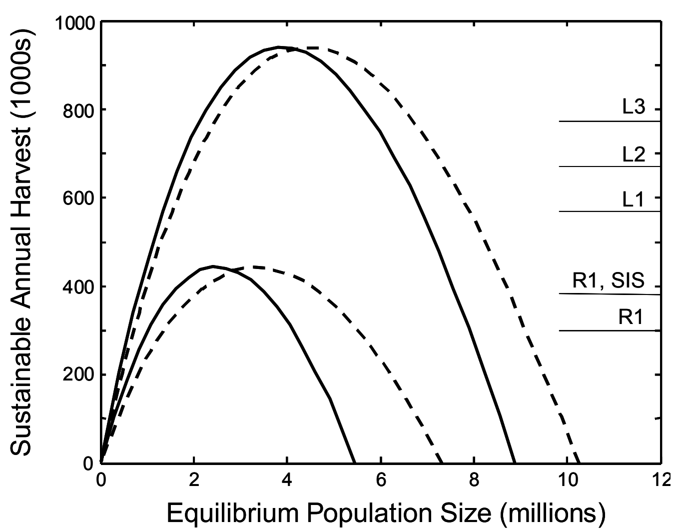



**Fig. 8.3.** Sustainable annual harvest of pintails as a function of equilibrium population size (solid lines: observed BPOP scale; dashed lines: latitude-corrected BPOP scale). The top curves are under environmental conditions that produce an average latitude of 53.6; the bottom curves assumes an average latitude of 55.6. The five horizontal reference lines show the expected continental harvest under a series of harvest packages (see Table 4.5), including a restrictive pintail season within a liberal duck season ("R1, SIS").

The two lower curves in Fig. 8.3 correspond to an average latitude of 55.6°N (the average since 1975). The carrying capacity has been reduced to about 7.3 million (on the corrected scale, 5.5 million on the observed scale), the maximum yield occurs when the population is held at 3.3 million (2.4 million on the observed scale), and the maximum sustainable harvest is a little bit more than what we expect under a restrictive pintail season within a liberal duck season. These graphs show the central tendencies under average environmental conditions; in wet years, of course, the harvest potential could allow for a liberal season. We think this graphical depiction of the change in harvest potential as a result of a long-term change in pintail dynamics has immediate harvest management implications and is important to keep in mind as we continue to evaluate pintail harvest policies.

Uncertainty about the harvest yield curves in Fig. 8.3 derives from several sources: uncertainty about the model structure itself; uncertainty about the parameter estimates within the model; and uncertainty about the appropriate mean latitude to consider. Two of the most important components of uncertainty in this model are the effects of density and latitude on recruitment. Density-dependence in recruitment is a key determinant of the yield curve, and the latitude effect is the key determinant of the difference between the yield curves pre- and post-1975. To understand the effects of parametric uncertainty in the recruitment relationship on the yield curves, we considered 4 additional recruitment models (Table 6.1), substituted them into the population model, and calculated the corresponding yield curves (Fig. 8.4). The additional

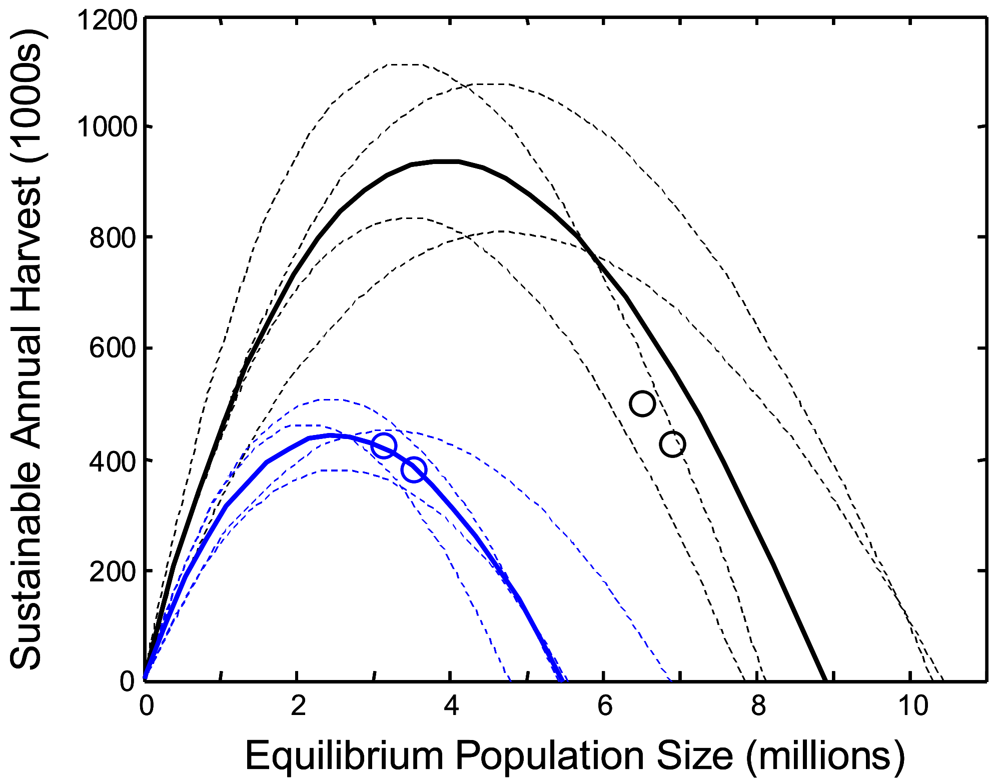



**Fig. 8.4.** Harvest yield curves, pre-1975 (black) and post-1975 (blue), for 5 alternative models. The *x*-axis is on the observed BPOP scale. The model formed from the maximum likelihood estimate for the recruitment parameters is shown with a bold line. Four alternative models derived from the 80% confidence ellipsoid for the recruitment parameters are shown with dashed lines. The four circles are described in Section 9.3.

models are taken from the 80% confidence ellipsoid of the parameter estimates for the recruitment relationship; models 3 and 4 are the extremes on that ellipsoid with regard to the latitude effect. The set of models shows that there is considerable uncertainty about the estimates of carrying capacity (both pre- and post-1975), as well as the estimates of optimal equilibrium population size and maximum sustainable harvest. Nevertheless, the shift in average latitude produces a substantial decrease in the productive capacity, hence the carrying capacity and the maximum sustainable harvest (Table 8.2). Across all models considered, the shift in average latitude results in a 31.1-46.2% decrease in carrying capacity, and a 39.1-64.7% decrease in sustainable harvest. Thus, even considering the uncertainty in the recruitment relationship, there is strong evidence that the carrying capacity and the sustainable yield have decreased.

**Table 8.2.** Equilibrium harvest properties for 5 pintail models, contrasting pre-1975 and post-1975 conditions. Quantities shown include: estimated carrying capacity (K), optimal equilibrium population size ($N_{eq}$*), maximum sustainable harvest ($H_{eq}$*), the change in carrying capacity pre-1975 to post-1975 (ΔK), and the change in sustainable harvest (ΔH).

| **Model** | **K** | | **$N_{eq}$*** | | **$H_{eq}$*** | | **ΔK** | **ΔH** |
|---|---|---|---|---|---|---|---|---|
| | **Pre75** | **Post75** | **Pre75** | **Post75** | **Pre75** | **Post75** | | |
| 0 (MLE) | 8.90 | 5.47 | 3.89 | 2.50 | 0.941 | 0.444 | –38.6% | –52.8% |
| 1 | 7.84 | 5.41 | 3.43 | 2.43 | 0.835 | 0.509 | –31.1 | –39.1 |
| 2 | 10.30 | 5.54 | 4.51 | 2.55 | 1.080 | 0.382 | –46.2 | –64.7 |
| 3 | 10.43 | 6.87 | 4.69 | 3.19 | 0.811 | 0.453 | –34.1 | –44.1 |
| 4 | 8.13 | 4.77 | 3.43 | 2.13 | 1.115 | 0.463 | –41.4 | –58.5 |

There are other sources of uncertainty besides the parametric uncertainty in the recruitment relationship. First, the functional form of the recruitment relationship can affect harvest dynamics (Runge and Johnson 2002); we have not yet explored different recruitment functions with this pintail model, but we believe the parametric uncertainty analysis above captures the likely range of results that alternative forms would produce. Second, the functional form of the survival relationship can also affect harvest dynamics. This population model, like the model from the original interim pintail harvest strategy, assumes an additive effect of harvest mortality. We have not explored alternative models for harvest mortality. We believe, however, that reasonable alternatives would likely serve to accentuate the differences pre- and post-1975. If harvest mortality is compensatory with natural mortality, the most plausible mechanism is through density-dependent winter survival. Thus, the compensatory effect should increase as a population approaches its winter carrying capacity and becomes more severely winter limited. In the case here, if changes on the breeding grounds have reduced the (summer) carrying capacity and hence the population size, then, all other things being equal, the population should be less winter limited, and hence, should show more additive effects of harvest mortality. This is because in a less winter-limited setting, there are more resources per individual, competition is reduced, and thus each death stands on its own—if an animal dies, that death does not free up any resources that would improve the survival chances of another animal. This argument lends support to the post-1975 yield curves shown in Figs. 8.3 and 8.4. If the pre-1975 populations were more winter limited, harvest may have been more compensatory, and the yield curves shown may be underestimated. Further exploration of these potential dynamics is warranted, but at this point, we believe the shift in dynamics as a result of a change in average latitude should be taken at face value.

Note that temporal variation does not produce uncertainty with regard to these curves—the curves are meant to be interpreted as the annual harvest under equilibrium conditions. While this is an abstraction (since a stochastic system is never at equilibrium), it is a fundamentally useful one. We believe we cannot understand the role of annual variation until we understand the deterministic backdrop against which it occurs.

## 9. Pintail Harvest Strategy

The pintail harvest strategy was modified in July 2004 as follows: "Season closed when the breeding population estimate (BPOP) is less than 1.5 million and the projected Fall Flight is less than 2.0 million. Partial season (restrictive alternative) when the BPOP or Fall Flight exceeds the closure level but the BPOP is less than 2.5 million and projections in the strategy predict a decline in the following year's BPOP (not including a 6% growth factor). Full season, minimum 1-bird daily bag limit when the BPOP exceeds 2.5 million, regardless of the following year's BPOP projection. All other existing provisions of the strategy continue to apply" (69 FR 52131). The purpose of this section is to investigate the properties of that strategy. We considered the technical modifications described above, but otherwise took the policy as it was. At this point, we have not looked at major changes, either in the general model structure or in the policy itself.

### *9.1. State-dependent Harvest Policy*

Incorporating the three technical improvements described above into the population model, we can calculate and depict this harvest strategy as in Fig. 9.1. The season would be closed when the *observed* BPOP is less than ~1 million (which is roughly equivalent to a corrected fall flight

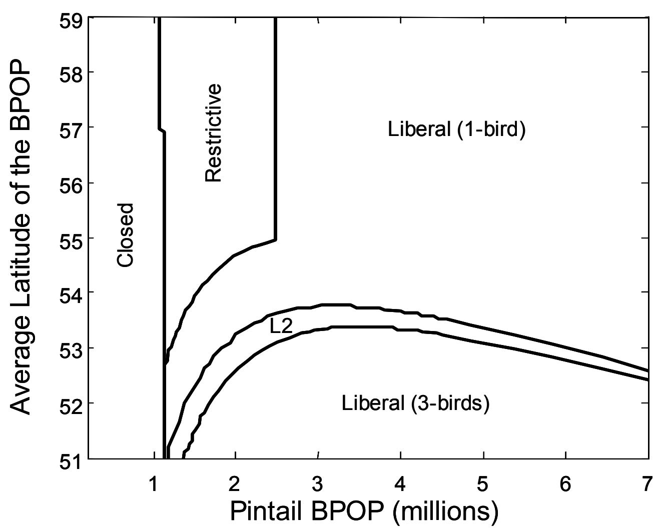



**Fig. 9.1.** Pintail harvest strategy, based on the July 2004 modifications and three technical improvements (overflight bias correction, new recruitment model, updated harvest models). For a given value of the *observed* (not corrected) pintail BPOP and average latitude of the BPOP, the resulting regulatory decision is shown. Note that this graph assumes the AHM package is "liberal", thus the "restrictive" regulation implies a season-within-a-season.

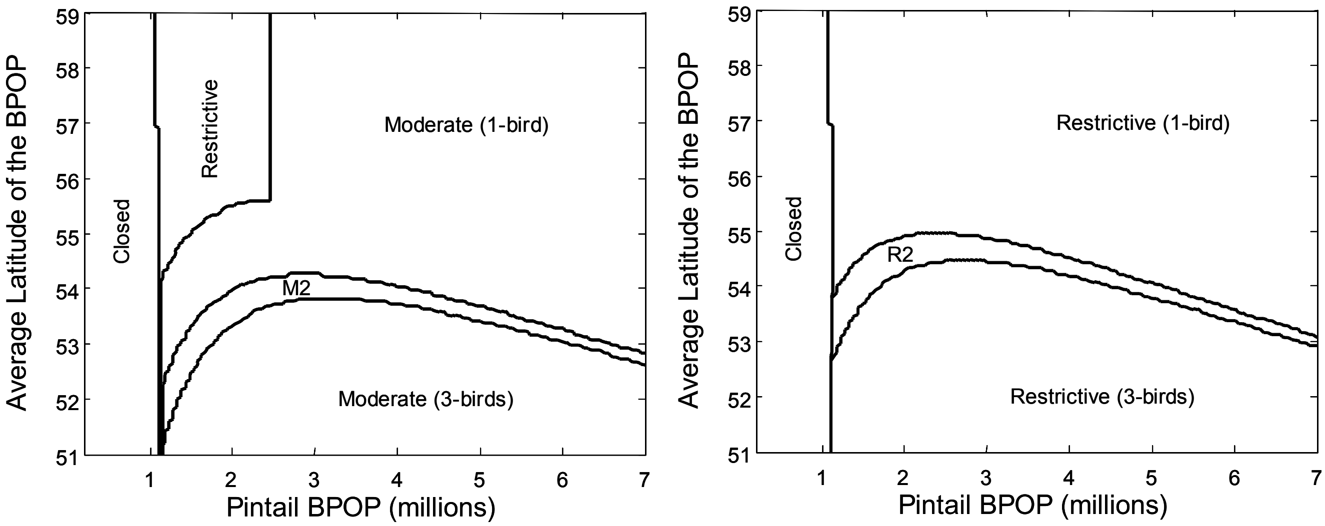



**Fig. 9.2.** State-dependent pintail harvest strategy, given (A) a moderate AHM package and (B) a restrictive AHM package. For details, see Fig. 9.1.

of 2 million), restrictive when the observed BPOP is less than 2.5 million with a high latitude of the BPOP, and liberal otherwise (this graph assumes the AHM package is liberal; the restrictive section of the graph implies a season-within-a-season). More than one bird in the bag is allowed when the population growth is expected to be greater than 6%. The corresponding state-dependent harvest policies when the AHM package is moderate or restrictive are shown in Fig. 9.2. When the AHM package is moderate, a restrictive season-within-a-season is possible. When the AHM package is restrictive, the pintail season is either also restrictive, or else closed. Bag limits greater than 1 are possible if the population growth is expected to be greater than 6%.

### *9.2. Comparison to Past Policy Decisions*

The past eight years of pintail regulations are shown in Table 9.1, along with the regulations that would be called for under the harvest strategy as modified in 2004, with and without the

**Table 9.1.** Regulations under the interim pintail harvest strategy, compared to regulations that would be have been called for using several modifications. "Regulation" gives the actual regulations enacted; "2004 Strategy" indicates what would be called for under the 2004 modifications to the pintail harvest strategy using the *old* population model; "2004+" indicates what would be called for under the 2004 strategy using the *new* population model (i.e., the technical modifications described above). "L3" refers to a liberal season length with three birds in the bag for all four flyways. "L3112" refers to a liberal season length with different bag limits in the four flyways (reading from west to east).

| Year | BPOP (obs) | Latitude | Regulation | 2004 Strategy | 2004+ |
|---|---|---|---|---|---|
| 1997 | 3.56 | 52.7 | L3 | L3112 | L3 |
| 1998 | 2.52 | 55.4 | L1 | L1 | L1 |
| 1999 | 3.06 | 54.6 | L1 | L1 | L1 |
| 2000 | 2.91 | 57.7 | L1 | L1 | L1 |
| 2001 | 3.30 | 55.8 | L1 | L1 | L1 |
| 2002 | 1.79 | 57.9 | R1 | R1 | R1 |
| 2003 | 2.56 | 55.3 | R1 | L1 | L1 |
| 2004 | 2.18 | 56.5 | R1 | R1 | R1 |

additional technical modifications described above. There are only two noteworthy differences in the table. First, the 2003 pintail season length would have been liberal, not season-within-a-season, under the 2004 strategy, because the observed population size was just above the threshold (2.5 million) that precludes a season-within-a-season. Second, the 1997 bag limits would have differed among flyways under the 2004 strategy but not the 2004+ strategy, because the BPOP correction in the 2004+ strategy predicts a larger allowable harvest. The harvest models were modified in 2002, which is why the actual regulation in 1997 differs from what's called for under the 2004 strategy.

### *9.3. Predicted Performance of the Harvest Strategy*

To investigate the predicted future performance of the pintail harvest strategy, we had to simulate the mid-continent mallard and pintail dynamics together, because the same variable—water on the prairies, either as measured by Canadian Ponds or pintail latitude—drives the dynamics of both species, and we wanted to be sure we had the right correlation structure for pintail latitude and AHM regulations. To do this, we used the existing AHM models, with the 2004 model weights (USFWS 2004) to simulate the number of Canadian Ponds and the corresponding AHM package under two scenarios: with and without inclusion of the North American Waterfowl Management Plan goal for mid-continent mallards in the AHM objective function. Next, we used equations (7.1) and (7.2) to generate corresponding values for Latitude of the pintail population under pre-1975 and post-1975 environmental conditions. Finally, we used the pintail population model described herein, with the updated harvest strategy (the "2004+" strategy), to simulate pintail dynamics and harvest.

With the North American goal included in the objective function (i.e., current policy) and with pre-1975 environmental conditions, pintail season lengths followed AHM regulations almost exactly (Table 9.2). If the AHM season length was liberal, the pintail season length was liberal;

**Table 9.2.** Predictive performance of the pintail harvest strategy under four scenarios: under pre-1975 and post-1975 environmental conditions; and with and without the North American Waterfowl Management Plan goal in the mid-continent mallard AHM objective function. The frequencies of the AHM packages and pintail regulations are shown; for the pintail regulations, only the season length is shown, different bag limits are lumped together. The observed pintail breeding population size and annual harvest are expressed in millions.

| | **With MCM NA goal** | | | **Without MCM NA goal** | | |
|---|---|---|---|---|---|---|
| | AHM Pkg | NOPI Pre | NOPI Post | AHM Pkg | NOPI Pre | NOPI Post |
| *Regulation Frequency* | | | | | | |
| Closed | 12 % | 12 % | 19 % | 14 % | 14 % | 22 % |
| Restrictive | 39 % | 39 % | 36 % | 6 % | 6 % | 5 % |
| R-SIS | -- | 0.1 % | 6 % | -- | 0.2 % | 18 % |
| Moderate | 8 % | 8 % | 6 % | 6 % | 6 % | 4 % |
| Liberal | 41 % | 41 % | 33 % | 73 % | 73 % | 50 % |
| *Average Population Size and Yield* | | | | | | |
| Mean BPOP (sd) | -- | 6.9 (1.7) | 3.7 (1.9) | -- | 6.6 (1.6) | 3.2 (1.7) |
| Mean Harv. (sd) | -- | 0.43 (0.19) | 0.38 (0.22) | -- | 0.50 (0.21) | 0.43 (0.24) |

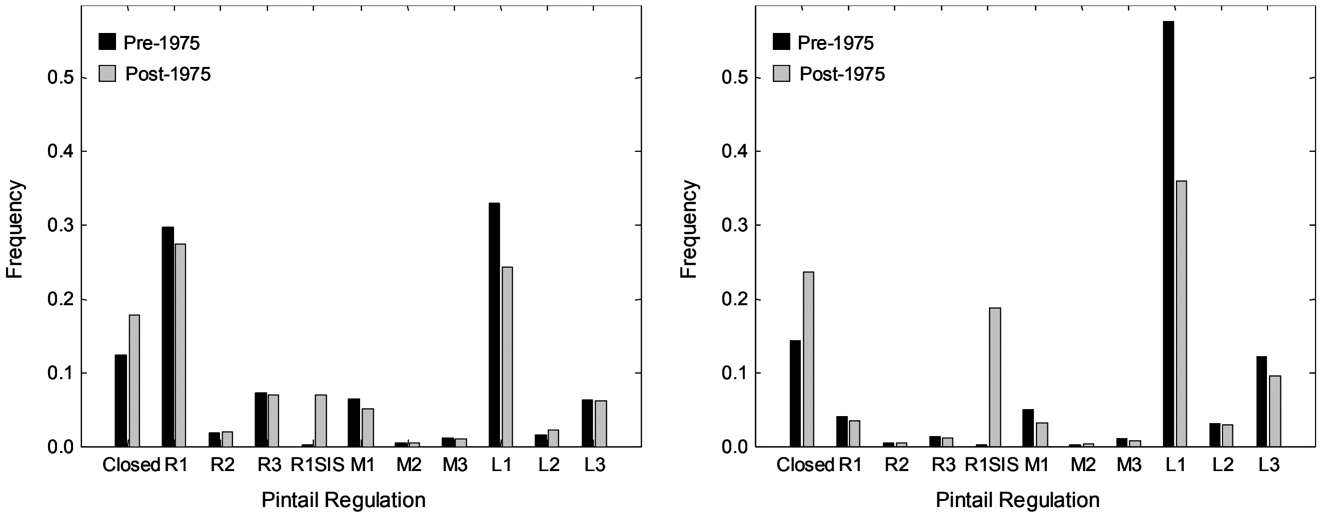



**Fig. 9.3.** Expected frequencies of pintail regulations under the 2004 harvest strategy, including the proposed technical modifications. Solid bars indicate pre-1975 environmental conditions (average pintail latitude); hatched bars indiciate post-1975 conditions. The regulations are indicated with a season length and bag limit (i.e., "R3" indicates a restrictive pintail season length with 3 birds in the bag). "R1SIS" denotes a restrictive pintail season within a longer duck season. (a) Left graph shows scenarios in which the North American goal is included in the AHM objective function. (b) Right graph shows scenarios in which the NA goal is not included.

when the AHM season was moderate, the pintail season was moderate, etc.; although there could be variation in pintail bag limit (Fig. 9.3a). Under this scenario, the expected long-term average pintail breeding population size was 6.9 million (on the observed scale), and the average annual harvest was 430,000 (this point is plotted on Fig. 8.4 for reference to the equilibrium yield curve). Since this point is far below the maximum sustained yield, this pintail policy is considerably more restrictive than what could have been supported, and indeed, what was practiced, prior to the mid-1970s. This conservatism is a result of the requirement for 6% growth to allow bag limits larger than 1.

Under post-1975 environmental conditions (but still including the North American goal), the pintail regulations begin to deviate somewhat from the AHM packages, with an increased frequency of restrictive (season-within-a-season) and closed pintail regulations, and a decreased frequency of liberal pintail regulations. Still, the expected deviation is not large—overall, the season-within-a-season (R-SIS) was only selected 6% of the time, and a closed pintail season with an open duck season occurred only 7% of the time (Table 9.2, Fig. 9.3a). The average pintail population size showed the effects of the loss of productivity, decreasing to 3.7 million (on the observed scale). The average annual harvest, at 380,000, however, did not decrease by much. Plotting this point on the equilibrium yield curve (Fig. 8.4) indicates that this policy is expected to manage the population closer to, but less than, the maximum sustained yield (444,000, see Table 8.2).

When the North American goal is not included in the AHM objective function, both the mid-continent mallard and pintail regulations become more liberal, and the effect of the change in environmental conditions is stronger. Again, under pre-1975 conditions, the pintail regulations track the AHM regulations very closely (Table 9.2, Fig. 9.3b). The expected pintail population size (6.6 million) is slightly lower than when the NA goal is included, and the harvest is higher (500,000, Table 9.2). Under post-1975 conditions, the restrictive season-within-a-season is called for 18% of the time, and closed pintail season during and open duck season occur 8% of the time, while the frequency of liberal pintail seasons drops to 50%. Without the NA goal in the AHM objective, the pintail policy manages the population very close to the maximum sustained yield (see point on Fig. 8.4).

## 10. Conclusion

### *10.1. Summary*

We believe that the technical improvements suggested above could be used to improve the predictive models used to assess northern pintail dynamics and inform harvest regulations. Most importantly, the overflight-bias correction (a) provides a way to remove the jumps in observed pintail population sizes brought about by changes in distribution rather than abundance; and (b) substantially improves the predictive ability of the population model. The other proposed modifications to the recruitment and harvest models are fairly routine updates. The end result is that technical improvements in model form, plus longer data sets, add up to a better predictive model for pintail dynamics.

This modeling structure allowed us to understand the implications of an apparent change in pintail dynamics in the mid-1970s. The latitude variable provides an important link that ties together pintail settling patterns and behavior with the demographic consequences. The shift to a more northward distribution, even after controlling for water availability, explains a decrease in reproduction at the continental level and predicts loss of carrying capacity and harvest potential. While the evidence suggests that the drop in pintail numbers has been driven by these changes in recruitment, not by harvest, there is nevertheless a real consequence for future harvest potential.

The existing harvest strategy, evaluated with the proposed technical modifications, (1) appears to be responsive to the loss of harvest potential by providing levels of harvest that are sustainable under the new system dynamics; (2) appears to be somewhat conservative in not trying to harvest at the maximum sustainable level; (3) is predicted to provide restrictive seasons-within-a-season fairly seldom, instead mostly following the AHM season length; and (4) is predicted to mostly call for 1-bird bag limits for pintails. The incorporation of the North American goal in the AHM objective function appears to be conferring some protection to pintails, in holding the pintail population size somewhat higher, in reducing the level of harvest, and in decreasing the frequency of seasons-within-a-season.

### *10.2. Future Steps*

There are a series of additional analyses that we can envision. First, we are interested in whether a balance-equation approach, developed like the mid-continent mallard models (Runge et al. 2002), would shed additional light on pintail dynamics. At least, a broader set of considerations concerning the model structure, including such things as a compensatory harvest mortality hypothesis, could be entertained. Second, it is possible to derive an optimal harvest strategy through methods like stochastic dynamic programming, provided that an explicit harvest management objective could be specified. Comparison of such an optimal policy to the current harvest strategy might help us understand the potential performance of the current strategy.

## 11. Acknowledgments

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## 13. Appendices

**Appendix 1. May aerial survey estimates for pintails.** The corrected BPOP is calculated using equation 5.4.

| Year | BPOP | SE of BPOP | Latitude | Longitude | BPOP (corrected) millions |
|---|---|---|---|---|---|
| 1960 | 5,722,160 | 323,233 | 53.78 | 114.60 | 6.6821 |
| 1961 | 4,218,159 | 496,169 | 55.77 | 118.22 | 5.7106 |
| 1962 | 3,623,524 | 243,150 | 54.23 | 118.44 | 4.3760 |
| 1963 | 3,846,015 | 255,565 | 54.18 | 118.91 | 4.6286 |
| 1964 | 3,291,227 | 239,393 | 54.73 | 119.95 | 4.1263 |
| 1965 | 3,591,918 | 221,851 | 53.78 | 116.47 | 4.1966 |
| 1966 | 4,811,934 | 265,557 | 52.62 | 114.94 | 5.1563 |
| 1967 | 5,277,693 | 341,940 | 52.14 | 113.73 | 5.4605 |
| 1968 | 3,489,395 | 244,623 | 56.61 | 128.25 | 5.0264 |
| 1969 | 5,903,888 | 296,191 | 51.68 | 111.91 | 5.9039 |
| 1970 | 6,391,987 | 396,727 | 51.96 | 112.36 | 6.5263 |
| 1971 | 5,847,204 | 368,133 | 51.74 | 111.07 | 5.8711 |
| 1972 | 6,978,954 | 364,513 | 52.69 | 113.89 | 7.5175 |
| 1973 | 4,356,220 | 266,988 | 54.76 | 121.42 | 5.4725 |
| 1974 | 6,598,182 | 345,810 | 53.06 | 115.32 | 7.3078 |
| 1975 | 5,900,370 | 267,326 | 52.58 | 113.17 | 6.3076 |
| 1976 | 5,475,644 | 299,161 | 53.23 | 115.29 | 6.1410 |
| 1977 | 3,926,093 | 246,802 | 58.86 | 133.74 | 6.6807 |
| 1978 | 5,108,179 | 267,756 | 52.69 | 116.60 | 5.5034 |
| 1979 | 5,376,133 | 274,413 | 52.33 | 114.31 | 5.6388 |
| 1980 | 4,508,077 | 228,608 | 56.94 | 127.53 | 6.6533 |
| 1981 | 3,479,479 | 260,506 | 57.59 | 130.29 | 5.3902 |
| 1982 | 3,708,758 | 226,559 | 53.06 | 116.99 | 4.1071 |
| 1983 | 3,510,642 | 178,068 | 55.05 | 120.27 | 4.5067 |
| 1984 | 2,964,801 | 166,782 | 56.03 | 123.82 | 4.0911 |
| 1985 | 2,515,493 | 142,969 | 55.14 | 121.54 | 3.2496 |
| 1986 | 2,739,747 | 152,100 | 54.85 | 122.08 | 3.4649 |
| 1987 | 2,628,344 | 159,412 | 55.83 | 126.06 | 3.5743 |
| 1988 | 2,005,522 | 164,048 | 59.06 | 136.70 | 3.4654 |
| 1989 | 2,111,902 | 181,253 | 56.88 | 128.87 | 3.1039 |
| 1990 | 2,256,630 | 183,280 | 57.81 | 132.69 | 3.5525 |
| 1991 | 1,803,385 | 131,280 | 59.81 | 136.31 | 3.2920 |
| 1992 | 2,098,139 | 160,972 | 57.66 | 130.02 | 3.2668 |
| 1993 | 2,053,418 | 124,184 | 55.95 | 126.46 | 2.8161 |
| 1994 | 2,972,266 | 188,005 | 53.56 | 120.31 | 3.4165 |
| 1995 | 2,757,866 | 177,594 | 53.73 | 119.92 | 3.2093 |
| 1996 | 2,735,863 | 147,542 | 53.51 | 120.61 | 3.1306 |
| 1997 | 3,557,991 | 194,237 | 52.71 | 116.09 | 3.8385 |
| 1998 | 2,520,649 | 136,806 | 55.39 | 125.77 | 3.3180 |
| 1999 | 3,057,888 | 230,532 | 54.61 | 123.58 | 3.7985 |
| 2000 | 2,907,559 | 170,467 | 57.74 | 131.56 | 4.5542 |
| 2001 | 3,295,994 | 266,584 | 55.85 | 127.25 | 4.4895 |
| 2002 | 1,789,710 | 125,199 | 57.91 | 134.13 | 2.8389 |
| 2003 | 2,558,229 | 174,797 | 55.29 | 124.72 | 3.3409 |
| 2004 | 2,184,602 | 155,233 | 56.50 | 129.00 | 3.1211 |

**Appendix 2. Direct recovery rates of pintails.**

| | Young Male | | Adult Male | | Young Female | | Adult Female | |
|---|---|---|---|---|---|---|---|---|
| Year | f | SE | f | SE | f | SE | f | SE |
| 1960 | 0.0590 | 0.0039 | 0.0250 | 0.0021 | 0.0455 | 0.0035 | 0.0217 | 0.0032 |
| 1961 | 0.0449 | 0.0044 | 0.0223 | 0.0018 | 0.0302 | 0.0037 | 0.0135 | 0.0019 |
| 1962 | 0.0376 | 0.0047 | 0.0209 | 0.0025 | 0.0291 | 0.0042 | 0.0227 | 0.0037 |
| 1963 | 0.0436 | 0.0044 | 0.0202 | 0.0026 | 0.0339 | 0.0038 | 0.0185 | 0.0037 |
| 1964 | 0.0385 | 0.0033 | 0.0246 | 0.0024 | 0.0373 | 0.0033 | 0.0281 | 0.0031 |
| 1965 | 0.0369 | 0.0032 | 0.0271 | 0.0033 | 0.0264 | 0.0026 | 0.0181 | 0.0030 |
| 1966 | 0.0449 | 0.0026 | 0.0206 | 0.0016 | 0.0329 | 0.0021 | 0.0162 | 0.0018 |
| 1967 | 0.0396 | 0.0023 | 0.0236 | 0.0018 | 0.0307 | 0.0018 | 0.0215 | 0.0020 |
| 1968 | 0.0382 | 0.0041 | 0.0177 | 0.0014 | 0.0236 | 0.0033 | 0.0140 | 0.0019 |
| 1969 | 0.0408 | 0.0028 | 0.0285 | 0.0035 | 0.0338 | 0.0026 | 0.0231 | 0.0030 |
| 1970 | 0.0432 | 0.0033 | 0.0275 | 0.0026 | 0.0415 | 0.0032 | 0.0256 | 0.0029 |
| 1971 | 0.0433 | 0.0035 | 0.0267 | 0.0025 | 0.0293 | 0.0029 | 0.0180 | 0.0023 |
| 1972 | 0.0379 | 0.0035 | 0.0292 | 0.0024 | 0.0308 | 0.0034 | 0.0162 | 0.0024 |
| 1973 | 0.0291 | 0.0039 | 0.0150 | 0.0019 | 0.0251 | 0.0036 | 0.0131 | 0.0022 |
| 1974 | 0.0334 | 0.0025 | 0.0156 | 0.0022 | 0.0276 | 0.0023 | 0.0159 | 0.0026 |
| 1975 | 0.0342 | 0.0029 | 0.0291 | 0.0028 | 0.0245 | 0.0025 | 0.0156 | 0.0024 |
| 1976 | 0.0316 | 0.0028 | 0.0224 | 0.0023 | 0.0295 | 0.0027 | 0.0162 | 0.0023 |
| 1977 | 0.0289 | 0.0034 | 0.0171 | 0.0016 | 0.0237 | 0.0031 | 0.0131 | 0.0017 |
| 1978 | 0.0342 | 0.0029 | 0.0214 | 0.0023 | 0.0228 | 0.0025 | 0.0137 | 0.0025 |
| 1979 | 0.0405 | 0.0026 | 0.0191 | 0.0022 | 0.0239 | 0.0021 | 0.0137 | 0.0022 |
| 1980 | 0.0397 | 0.0040 | 0.0186 | 0.0024 | 0.0270 | 0.0034 | 0.0125 | 0.0023 |
| 1981 | 0.0334 | 0.0048 | 0.0180 | 0.0034 | 0.0245 | 0.0041 | 0.0116 | 0.0028 |
| 1982 | 0.0363 | 0.0049 | 0.0212 | 0.0038 | 0.0154 | 0.0031 | 0.0159 | 0.0030 |
| 1983 | 0.0318 | 0.0034 | 0.0187 | 0.0031 | 0.0295 | 0.0030 | 0.0134 | 0.0026 |
| 1984 | 0.0239 | 0.0038 | 0.0135 | 0.0026 | 0.0244 | 0.0037 | 0.0135 | 0.0027 |
| 1985 | 0.0262 | 0.0038 | 0.0112 | 0.0028 | 0.0199 | 0.0032 | 0.0065 | 0.0020 |
| 1986 | 0.0255 | 0.0031 | 0.0187 | 0.0029 | 0.0175 | 0.0025 | 0.0090 | 0.0021 |
| 1987 | 0.0282 | 0.0042 | 0.0161 | 0.0024 | 0.0161 | 0.0032 | 0.0084 | 0.0020 |
| 1988 | 0.0175 | 0.0050 | 0.0075 | 0.0014 | 0.0092 | 0.0035 | 0.0057 | 0.0014 |
| 1989 | 0.0203 | 0.0037 | 0.0052 | 0.0016 | 0.0114 | 0.0028 | 0.0082 | 0.0021 |
| 1990 | 0.0195 | 0.0032 | 0.0069 | 0.0013 | 0.0111 | 0.0023 | 0.0067 | 0.0015 |
| 1991 | 0.0179 | 0.0031 | 0.0073 | 0.0017 | 0.0126 | 0.0027 | 0.0047 | 0.0013 |
| 1992 | 0.0272 | 0.0037 | 0.0124 | 0.0015 | 0.0215 | 0.0031 | 0.0062 | 0.0012 |
| 1993 | 0.0262 | 0.0033 | 0.0120 | 0.0021 | 0.0163 | 0.0025 | 0.0071 | 0.0018 |
| 1994 | 0.0194 | 0.0023 | 0.0124 | 0.0021 | 0.0159 | 0.0020 | 0.0078 | 0.0018 |
| 1995 | 0.0284 | 0.0033 | 0.0188 | 0.0022 | 0.0239 | 0.0028 | 0.0129 | 0.0020 |
| 1996 | 0.0335 | 0.0036 | 0.0124 | 0.0018 | 0.0197 | 0.0026 | 0.0090 | 0.0015 |
| 1997 | 0.0460 | 0.0033 | 0.0250 | 0.0032 | 0.0328 | 0.0024 | 0.0145 | 0.0020 |
| 1998 | 0.0535 | 0.0046 | 0.0305 | 0.0025 | 0.0352 | 0.0036 | 0.0129 | 0.0017 |
| 1999 | 0.0618 | 0.0056 | 0.0334 | 0.0034 | 0.0500 | 0.0044 | 0.0232 | 0.0026 |
| 2000 | 0.0666 | 0.0061 | 0.0313 | 0.0025 | 0.0476 | 0.0048 | 0.0203 | 0.0020 |
| 2001 | 0.0643 | 0.0063 | 0.0278 | 0.0026 | 0.0466 | 0.0047 | 0.0154 | 0.0019 |
| 2002 | 0.0436 | 0.0052 | 0.0191 | 0.0029 | 0.0416 | 0.0046 | 0.0137 | 0.0024 |
| 2003 | 0.0426 | 0.0036 | 0.0174 | 0.0029 | 0.0303 | 0.0029 | 0.0116 | 0.0020 |

**Appendix 3. Pintail relative vulnerability to the US harvest, and female harvest and population age ratios.**

| Year | Male Vulnerabilty | SE | Female Vulnerabilty | SE | Female harvest age ratio | Female population age ratio |
|---|---|---|---|---|---|---|
| 1961 | 2.0137 | 0.2550 | 2.2286 | 0.4184 | 1.0981877 | 0.4927607 |
| 1962 | 1.8026 | 0.3100 | 1.2821 | 0.2803 | 1.4467156 | 1.1284102 |
| 1963 | 2.1545 | 0.3508 | 1.8316 | 0.4176 | 2.0222369 | 1.1040903 |
| 1964 | 1.5653 | 0.2036 | 1.3247 | 0.1862 | 1.62864 | 1.229418 |
| 1965 | 1.3640 | 0.2054 | 1.4540 | 0.2783 | 3.1222932 | 2.1474382 |
| 1966 | 2.1780 | 0.2125 | 2.0300 | 0.2619 | 2.1198433 | 1.0442514 |
| 1967 | 1.6743 | 0.1615 | 1.4278 | 0.1599 | 2.4251812 | 1.6985448 |
| 1968 | 2.1558 | 0.2879 | 1.6803 | 0.3266 | 1.0962068 | 0.6523926 |
| 1969 | 1.4298 | 0.2033 | 1.4648 | 0.2214 | 2.9874863 | 2.0394568 |
| 1970 | 1.5671 | 0.1914 | 1.6180 | 0.2219 | 1.9900335 | 1.2299615 |
| 1971 | 1.6236 | 0.2010 | 1.6266 | 0.2627 | 1.5003959 | 0.9223856 |
| 1972 | 1.2999 | 0.1633 | 1.9003 | 0.3519 | 1.5926621 | 0.8381097 |
| 1973 | 1.9376 | 0.3527 | 1.9183 | 0.4225 | 1.2150599 | 0.6334104 |
| 1974 | 2.1427 | 0.3445 | 1.7413 | 0.3217 | 2.1053845 | 1.2090873 |
| 1975 | 1.1771 | 0.1513 | 1.5699 | 0.2859 | 1.7213364 | 1.0964296 |
| 1976 | 1.4138 | 0.1887 | 1.8174 | 0.3028 | 1.693397 | 0.9317625 |
| 1977 | 1.6911 | 0.2506 | 1.8131 | 0.3381 | 1.0355985 | 0.5711825 |
| 1978 | 1.5949 | 0.2200 | 1.6630 | 0.3544 | 2.4134554 | 1.4512408 |
| 1979 | 2.1239 | 0.2785 | 1.7486 | 0.3161 | 2.0022622 | 1.1450421 |
| 1980 | 2.1339 | 0.3468 | 2.1531 | 0.4735 | 1.0340407 | 0.4802499 |
| 1981 | 1.8571 | 0.4449 | 2.1179 | 0.6211 | 1.2394886 | 0.5852458 |
| 1982 | 1.7099 | 0.3854 | 0.9729 | 0.2685 | 1.5456639 | 1.5887206 |
| 1983 | 1.7009 | 0.3389 | 2.2035 | 0.4788 | 1.8597628 | 0.8439904 |
| 1984 | 1.7664 | 0.4433 | 1.8069 | 0.4505 | 1.620685 | 0.8969284 |
| 1985 | 2.3487 | 0.6747 | 3.0769 | 1.0885 | 1.9554672 | 0.6355218 |
| 1986 | 1.3688 | 0.2681 | 1.9381 | 0.5208 | 2.1429956 | 1.1057032 |
| 1987 | 1.7485 | 0.3666 | 1.9189 | 0.5997 | 1.4420961 | 0.7515389 |
| 1988 | 2.3213 | 0.7870 | 1.6195 | 0.7243 | 1.1845318 | 0.7314347 |
| 1989 | 3.8787 | 1.3670 | 1.3892 | 0.4897 | 2.1369003 | 1.5381712 |
| 1990 | 2.8063 | 0.6893 | 1.6545 | 0.4972 | 2.1245967 | 1.2841516 |
| 1991 | 2.4506 | 0.7058 | 2.7124 | 0.9452 | 1.6749028 | 0.6175086 |
| 1992 | 2.1940 | 0.4019 | 3.4577 | 0.8510 | 2.0077461 | 0.5806563 |
| 1993 | 2.1909 | 0.4708 | 2.3053 | 0.6718 | 2.3789047 | 1.0319181 |
| 1994 | 1.5614 | 0.3296 | 2.0435 | 0.5435 | 2.7228894 | 1.3324599 |
| 1995 | 1.5128 | 0.2492 | 1.8503 | 0.3646 | 1.7939586 | 0.9695714 |
| 1996 | 2.7069 | 0.4881 | 2.1719 | 0.4642 | 2.0975601 | 0.9657527 |
| 1997 | 1.8442 | 0.2714 | 2.2642 | 0.3569 | 3.0646875 | 1.353515 |
| 1998 | 1.7555 | 0.2071 | 2.7182 | 0.4475 | 1.7321089 | 0.6372258 |
| 1999 | 1.8504 | 0.2503 | 2.1571 | 0.3107 | 2.0450855 | 0.9480774 |
| 2000 | 2.1249 | 0.2559 | 2.3457 | 0.3320 | 1.4341233 | 0.6113802 |
| 2001 | 2.3171 | 0.3149 | 3.0202 | 0.4760 | 1.8863663 | 0.6245928 |
| 2002 | 2.2820 | 0.4414 | 3.0396 | 0.6254 | 2.0190861 | 0.6642518 |
| 2003 | 2.4503 | 0.4547 | 2.6092 | 0.5095 | 2.9889352 | 1.1455408 |

**Appendix 4. Adult male pintail annual survival and recovery rates.**

| Male | Adult | | 95% CI | | Adult | | 95% CI | |
|---|---|---|---|---|---|---|---|---|
| Year | S | SE | Lower | Upper | f | SE | Lower | Upper |
| 1960 | 0.7013 | 0.0454 | 0.6055 | 0.7822 | 0.0266 | 0.0022 | 0.0227 | 0.0312 |
| 1961 | 0.6669 | 0.0448 | 0.5743 | 0.7482 | 0.0234 | 0.0015 | 0.0206 | 0.0264 |
| 1962 | 0.8892 | 0.0713 | 0.6602 | 0.9707 | 0.0208 | 0.0016 | 0.0180 | 0.0241 |
| 1963 | 0.6506 | 0.0511 | 0.5452 | 0.7431 | 0.0264 | 0.0019 | 0.0229 | 0.0305 |
| 1964 | 0.6749 | 0.0540 | 0.5617 | 0.7708 | 0.0262 | 0.0017 | 0.0231 | 0.0297 |
| 1965 | 0.8507 | 0.0623 | 0.6854 | 0.9371 | 0.0237 | 0.0018 | 0.0203 | 0.0275 |
| 1966 | 0.7704 | 0.0428 | 0.6762 | 0.8435 | 0.0236 | 0.0012 | 0.0213 | 0.0262 |
| 1967 | 0.6996 | 0.0383 | 0.6197 | 0.7689 | 0.0263 | 0.0013 | 0.0238 | 0.0290 |
| 1968 | 0.5976 | 0.0430 | 0.5112 | 0.6784 | 0.0216 | 0.0010 | 0.0196 | 0.0237 |
| 1969 | 0.7285 | 0.0566 | 0.6049 | 0.8247 | 0.0265 | 0.0019 | 0.0231 | 0.0305 |
| 1970 | 0.7869 | 0.0531 | 0.6649 | 0.8729 | 0.0347 | 0.0019 | 0.0312 | 0.0386 |
| 1971 | 0.6472 | 0.0425 | 0.5601 | 0.7254 | 0.0280 | 0.0016 | 0.0250 | 0.0313 |
| 1972 | 0.8216 | 0.0545 | 0.6897 | 0.9051 | 0.0295 | 0.0016 | 0.0265 | 0.0328 |
| 1973 | 0.6944 | 0.0516 | 0.5852 | 0.7854 | 0.0223 | 0.0014 | 0.0198 | 0.0251 |
| 1974 | 0.6847 | 0.0518 | 0.5757 | 0.7766 | 0.0272 | 0.0018 | 0.0239 | 0.0309 |
| 1975 | 0.7472 | 0.0530 | 0.6303 | 0.8367 | 0.0311 | 0.0019 | 0.0277 | 0.0350 |
| 1976 | 0.7409 | 0.0473 | 0.6383 | 0.8225 | 0.0287 | 0.0017 | 0.0256 | 0.0321 |
| 1977 | 0.7151 | 0.0472 | 0.6146 | 0.7981 | 0.0227 | 0.0012 | 0.0205 | 0.0252 |
| 1978 | 0.7459 | 0.0555 | 0.6232 | 0.8390 | 0.0248 | 0.0015 | 0.0220 | 0.0280 |
| 1979 | 0.8651 | 0.0724 | 0.6552 | 0.9559 | 0.0253 | 0.0016 | 0.0224 | 0.0286 |
| 1980 | 0.6472 | 0.0733 | 0.4943 | 0.7748 | 0.0226 | 0.0016 | 0.0196 | 0.0259 |
| 1981 | 0.6184 | 0.0783 | 0.4581 | 0.7564 | 0.0180 | 0.0018 | 0.0147 | 0.0220 |
| 1982 | 0.9837 | 0.1228 | 0.0000 | 1.0000 | 0.0258 | 0.0025 | 0.0214 | 0.0311 |
| 1983 | 0.6457 | 0.0812 | 0.4761 | 0.7852 | 0.0216 | 0.0021 | 0.0178 | 0.0261 |
| 1984 | 0.7608 | 0.1040 | 0.5093 | 0.9070 | 0.0188 | 0.0019 | 0.0154 | 0.0228 |
| 1985 | 0.6500 | 0.0862 | 0.4691 | 0.7961 | 0.0180 | 0.0021 | 0.0143 | 0.0226 |
| 1986 | 0.7391 | 0.0807 | 0.5550 | 0.8656 | 0.0179 | 0.0017 | 0.0148 | 0.0216 |
| 1987 | 0.8277 | 0.0835 | 0.6040 | 0.9380 | 0.0209 | 0.0018 | 0.0176 | 0.0247 |
| 1988 | 0.6754 | 0.0730 | 0.5201 | 0.7998 | 0.0095 | 0.0009 | 0.0079 | 0.0115 |
| 1989 | 0.8726 | 0.0906 | 0.5809 | 0.9713 | 0.0117 | 0.0013 | 0.0094 | 0.0144 |
| 1990 | 0.6807 | 0.0640 | 0.5447 | 0.7916 | 0.0120 | 0.0010 | 0.0102 | 0.0142 |
| 1991 | 0.7556 | 0.0649 | 0.6082 | 0.8603 | 0.0108 | 0.0011 | 0.0089 | 0.0131 |
| 1992 | 0.7726 | 0.0612 | 0.6318 | 0.8705 | 0.0144 | 0.0010 | 0.0125 | 0.0166 |
| 1993 | 0.8334 | 0.0757 | 0.6323 | 0.9357 | 0.0155 | 0.0013 | 0.0132 | 0.0182 |
| 1994 | 0.8047 | 0.0681 | 0.6379 | 0.9060 | 0.0161 | 0.0013 | 0.0137 | 0.0189 |
| 1995 | 0.8265 | 0.0650 | 0.6621 | 0.9205 | 0.0195 | 0.0013 | 0.0171 | 0.0223 |
| 1996 | 0.5919 | 0.0499 | 0.4918 | 0.6850 | 0.0170 | 0.0012 | 0.0148 | 0.0196 |
| 1997 | 0.7564 | 0.0580 | 0.6263 | 0.8519 | 0.0260 | 0.0019 | 0.0225 | 0.0300 |
| 1998 | 0.7436 | 0.0561 | 0.6196 | 0.8378 | 0.0325 | 0.0017 | 0.0292 | 0.0361 |
| 1999 | 0.8206 | 0.0670 | 0.6522 | 0.9177 | 0.0337 | 0.0023 | 0.0295 | 0.0384 |
| 2000 | 0.7035 | 0.0619 | 0.5700 | 0.8094 | 0.0296 | 0.0018 | 0.0264 | 0.0333 |
| 2001 | 0.8539 | 0.1232 | 0.4577 | 0.9759 | 0.0289 | 0.0021 | 0.0250 | 0.0333 |
| 2002 | 0.6227 | 0.1288 | 0.3604 | 0.8286 | 0.0174 | 0.0022 | 0.0135 | 0.0223 |
| 2003 | | | | | 0.0189 | 0.0030 | 0.0138 | 0.0257 |

## Appendix 5. Young male pintail annual survival and recovery rates.

| Male | Young | | 95% CI | | Young | | 95% CI | |
|---|---|---|---|---|---|---|---|---|
| Year | S | SE | Lower | Upper | f | SE | Lower | Upper |
| 1960 | 0.4459 | 0.0403 | 0.3689 | 0.5255 | 0.0670 | 0.0042 | 0.0593 | 0.0756 |
| 1961 | 0.4190 | 0.0482 | 0.3285 | 0.5152 | 0.0517 | 0.0047 | 0.0432 | 0.0618 |
| 1962 | 0.6285 | 0.0747 | 0.4746 | 0.7601 | 0.0426 | 0.0050 | 0.0338 | 0.0536 |
| 1963 | 0.5202 | 0.0555 | 0.4122 | 0.6263 | 0.0519 | 0.0048 | 0.0433 | 0.0622 |
| 1964 | 0.5649 | 0.0530 | 0.4597 | 0.6646 | 0.0493 | 0.0037 | 0.0424 | 0.0571 |
| 1965 | 0.6105 | 0.0484 | 0.5126 | 0.7002 | 0.0533 | 0.0038 | 0.0463 | 0.0612 |
| 1966 | 0.6383 | 0.0416 | 0.5536 | 0.7152 | 0.0582 | 0.0029 | 0.0528 | 0.0642 |
| 1967 | 0.6384 | 0.0382 | 0.5608 | 0.7094 | 0.0516 | 0.0026 | 0.0468 | 0.0569 |
| 1968 | 0.5192 | 0.0560 | 0.4103 | 0.6264 | 0.0509 | 0.0047 | 0.0425 | 0.0609 |
| 1969 | 0.5633 | 0.0406 | 0.4827 | 0.6407 | 0.0509 | 0.0031 | 0.0451 | 0.0575 |
| 1970 | 0.6274 | 0.0507 | 0.5240 | 0.7203 | 0.0626 | 0.0040 | 0.0553 | 0.0708 |
| 1971 | 0.6046 | 0.0484 | 0.5070 | 0.6945 | 0.0571 | 0.0040 | 0.0497 | 0.0655 |
| 1972 | 0.6323 | 0.0571 | 0.5151 | 0.7357 | 0.0530 | 0.0042 | 0.0455 | 0.0618 |
| 1973 | 0.6135 | 0.0662 | 0.4787 | 0.7328 | 0.0458 | 0.0049 | 0.0372 | 0.0564 |
| 1974 | 0.5419 | 0.0420 | 0.4593 | 0.6224 | 0.0440 | 0.0029 | 0.0386 | 0.0500 |
| 1975 | 0.5799 | 0.0476 | 0.4849 | 0.6693 | 0.0478 | 0.0034 | 0.0416 | 0.0549 |
| 1976 | 0.6216 | 0.0480 | 0.5240 | 0.7102 | 0.0470 | 0.0033 | 0.0409 | 0.0540 |
| 1977 | 0.6349 | 0.0614 | 0.5084 | 0.7451 | 0.0426 | 0.0040 | 0.0353 | 0.0512 |
| 1978 | 0.5772 | 0.0508 | 0.4758 | 0.6725 | 0.0439 | 0.0033 | 0.0378 | 0.0508 |
| 1979 | 0.7801 | 0.0658 | 0.6259 | 0.8827 | 0.0553 | 0.0030 | 0.0497 | 0.0615 |
| 1980 | 0.6996 | 0.0898 | 0.5019 | 0.8433 | 0.0517 | 0.0046 | 0.0434 | 0.0614 |
| 1981 | 0.6001 | 0.0855 | 0.4274 | 0.7510 | 0.0421 | 0.0054 | 0.0327 | 0.0541 |
| 1982 | 0.7317 | 0.1083 | 0.4804 | 0.8895 | 0.0458 | 0.0055 | 0.0362 | 0.0578 |
| 1983 | 0.6719 | 0.0846 | 0.4911 | 0.8129 | 0.0425 | 0.0039 | 0.0354 | 0.0510 |
| 1984 | 0.6753 | 0.1070 | 0.4442 | 0.8441 | 0.0349 | 0.0045 | 0.0270 | 0.0450 |
| 1985 | 0.6964 | 0.0933 | 0.4913 | 0.8449 | 0.0324 | 0.0042 | 0.0251 | 0.0417 |
| 1986 | 0.8434 | 0.0923 | 0.5780 | 0.9549 | 0.0358 | 0.0037 | 0.0292 | 0.0437 |
| 1987 | 0.9537 | 0.1225 | 0.0825 | 0.9998 | 0.0390 | 0.0049 | 0.0305 | 0.0498 |
| 1988 | 0.7934 | 0.1465 | 0.3999 | 0.9568 | 0.0262 | 0.0061 | 0.0166 | 0.0413 |
| 1989 | 0.6855 | 0.0966 | 0.4753 | 0.8398 | 0.0344 | 0.0048 | 0.0261 | 0.0452 |
| 1990 | 0.6857 | 0.0856 | 0.5003 | 0.8261 | 0.0270 | 0.0038 | 0.0206 | 0.0355 |
| 1991 | 0.6799 | 0.0743 | 0.5209 | 0.8057 | 0.0290 | 0.0040 | 0.0222 | 0.0379 |
| 1992 | 0.6796 | 0.0755 | 0.5181 | 0.8072 | 0.0379 | 0.0043 | 0.0303 | 0.0474 |
| 1993 | 0.6863 | 0.0733 | 0.5287 | 0.8101 | 0.0354 | 0.0039 | 0.0286 | 0.0438 |
| 1994 | 0.8141 | 0.0674 | 0.6466 | 0.9129 | 0.0287 | 0.0028 | 0.0236 | 0.0348 |
| 1995 | 0.7206 | 0.0721 | 0.5610 | 0.8388 | 0.0384 | 0.0038 | 0.0316 | 0.0467 |
| 1996 | 0.5388 | 0.0558 | 0.4293 | 0.6447 | 0.0403 | 0.0039 | 0.0333 | 0.0487 |
| 1997 | 0.6244 | 0.0470 | 0.5288 | 0.7112 | 0.0542 | 0.0036 | 0.0476 | 0.0616 |
| 1998 | 0.5913 | 0.0619 | 0.4669 | 0.7050 | 0.0621 | 0.0049 | 0.0532 | 0.0724 |
| 1999 | 0.8516 | 0.0919 | 0.5797 | 0.9598 | 0.0688 | 0.0059 | 0.0581 | 0.0813 |
| 2000 | 0.7521 | 0.1026 | 0.5079 | 0.8992 | 0.0719 | 0.0063 | 0.0605 | 0.0853 |
| 2001 | 0.9916 | 0.1937 | 0.0000 | 1.0000 | 0.0749 | 0.0067 | 0.0627 | 0.0892 |
| 2002 | 0.6470 | 0.1797 | 0.2816 | 0.8955 | 0.0462 | 0.0053 | 0.0368 | 0.0578 |
| 2003 | | | | | 0.0519 | 0.0040 | 0.0446 | 0.0602 |

## Appendix 6. Adult female pintail annual survival and recovery rates.

| Female | Adult | | 95% CI | | Adult | | 95% CI | |
|---|---|---|---|---|---|---|---|---|
| Year | S | SE | Lower | Upper | f | SE | Lower | Upper |
| 1960 | 0.7662 | 0.1077 | 0.5021 | 0.9141 | 0.0242 | 0.0034 | 0.0183 | 0.0319 |
| 1961 | 0.5577 | 0.0761 | 0.4078 | 0.6978 | 0.0152 | 0.0017 | 0.0122 | 0.0188 |
| 1962 | 0.6193 | 0.0956 | 0.4236 | 0.7827 | 0.0161 | 0.0021 | 0.0124 | 0.0209 |
| 1963 | 0.6100 | 0.0816 | 0.4441 | 0.7539 | 0.0210 | 0.0027 | 0.0163 | 0.0270 |
| 1964 | 0.6474 | 0.0790 | 0.4824 | 0.7834 | 0.0281 | 0.0025 | 0.0237 | 0.0333 |
| 1965 | 0.7376 | 0.0843 | 0.5449 | 0.8684 | 0.0185 | 0.0021 | 0.0148 | 0.0230 |
| 1966 | 0.5492 | 0.0481 | 0.4543 | 0.6406 | 0.0193 | 0.0015 | 0.0166 | 0.0225 |
| 1967 | 0.6375 | 0.0574 | 0.5195 | 0.7410 | 0.0234 | 0.0016 | 0.0205 | 0.0268 |
| 1968 | 0.5817 | 0.0591 | 0.4634 | 0.6912 | 0.0183 | 0.0014 | 0.0156 | 0.0213 |
| 1969 | 0.6427 | 0.0664 | 0.5051 | 0.7602 | 0.0222 | 0.0019 | 0.0187 | 0.0264 |
| 1970 | 0.7983 | 0.0829 | 0.5906 | 0.9156 | 0.0278 | 0.0022 | 0.0239 | 0.0324 |
| 1971 | 0.6321 | 0.0725 | 0.4825 | 0.7600 | 0.0199 | 0.0017 | 0.0168 | 0.0235 |
| 1972 | 0.6578 | 0.0825 | 0.4838 | 0.7978 | 0.0202 | 0.0019 | 0.0168 | 0.0243 |
| 1973 | 0.5654 | 0.0741 | 0.4187 | 0.7014 | 0.0164 | 0.0017 | 0.0134 | 0.0200 |
| 1974 | 0.7324 | 0.0961 | 0.5114 | 0.8774 | 0.0181 | 0.0019 | 0.0147 | 0.0224 |
| 1975 | 0.5008 | 0.0622 | 0.3812 | 0.6203 | 0.0193 | 0.0019 | 0.0159 | 0.0234 |
| 1976 | 0.7166 | 0.0814 | 0.5355 | 0.8472 | 0.0195 | 0.0018 | 0.0162 | 0.0234 |
| 1977 | 0.5918 | 0.0757 | 0.4395 | 0.7283 | 0.0154 | 0.0014 | 0.0129 | 0.0183 |
| 1978 | 0.6604 | 0.0918 | 0.4658 | 0.8127 | 0.0170 | 0.0019 | 0.0136 | 0.0212 |
| 1979 | 0.6384 | 0.0891 | 0.4532 | 0.7900 | 0.0152 | 0.0016 | 0.0124 | 0.0188 |
| 1980 | 0.7797 | 0.1107 | 0.5003 | 0.9260 | 0.0170 | 0.0019 | 0.0136 | 0.0211 |
| 1981 | 0.4359 | 0.0649 | 0.3154 | 0.5645 | 0.0099 | 0.0011 | 0.0079 | 0.0124 |
| 1982 | 0.7507 | 0.1245 | 0.4499 | 0.9173 | 0.0177 | 0.0022 | 0.0138 | 0.0227 |
| 1983 | 0.5052 | 0.0875 | 0.3396 | 0.6696 | 0.0164 | 0.0021 | 0.0127 | 0.0211 |
| 1984 | 0.8483 | 0.1740 | 0.2831 | 0.9875 | 0.0165 | 0.0022 | 0.0127 | 0.0214 |
| 1985 | 0.4519 | 0.0929 | 0.2833 | 0.6323 | 0.0097 | 0.0017 | 0.0068 | 0.0137 |
| 1986 | 0.6808 | 0.1237 | 0.4113 | 0.8669 | 0.0130 | 0.0018 | 0.0099 | 0.0172 |
| 1987 | 0.8337 | 0.1606 | 0.3410 | 0.9798 | 0.0135 | 0.0019 | 0.0102 | 0.0179 |
| 1988 | 0.4282 | 0.0825 | 0.2790 | 0.5917 | 0.0058 | 0.0010 | 0.0042 | 0.0080 |
| 1989 | 0.8946 | 0.1652 | 0.2148 | 0.9962 | 0.0104 | 0.0017 | 0.0076 | 0.0143 |
| 1990 | 0.7449 | 0.1384 | 0.4119 | 0.9241 | 0.0076 | 0.0011 | 0.0057 | 0.0102 |
| 1991 | 0.5836 | 0.1010 | 0.3829 | 0.7599 | 0.0054 | 0.0009 | 0.0039 | 0.0075 |
| 1992 | 0.4897 | 0.0761 | 0.3457 | 0.6354 | 0.0072 | 0.0010 | 0.0055 | 0.0094 |
| 1993 | 0.6496 | 0.1006 | 0.4380 | 0.8151 | 0.0083 | 0.0012 | 0.0062 | 0.0111 |
| 1994 | 0.8111 | 0.1146 | 0.4977 | 0.9490 | 0.0105 | 0.0014 | 0.0080 | 0.0136 |
| 1995 | 0.7073 | 0.0919 | 0.5030 | 0.8523 | 0.0123 | 0.0014 | 0.0099 | 0.0153 |
| 1996 | 0.5984 | 0.0744 | 0.4481 | 0.7322 | 0.0113 | 0.0012 | 0.0092 | 0.0138 |
| 1997 | 0.6132 | 0.0709 | 0.4688 | 0.7401 | 0.0124 | 0.0013 | 0.0101 | 0.0152 |
| 1998 | 0.5187 | 0.0563 | 0.4091 | 0.6264 | 0.0147 | 0.0013 | 0.0123 | 0.0174 |
| 1999 | 0.7499 | 0.0838 | 0.5554 | 0.8780 | 0.0232 | 0.0020 | 0.0195 | 0.0275 |
| 2000 | 0.5813 | 0.0714 | 0.4386 | 0.7116 | 0.0197 | 0.0016 | 0.0168 | 0.0232 |
| 2001 | 0.5610 | 0.0937 | 0.3775 | 0.7292 | 0.0155 | 0.0015 | 0.0128 | 0.0188 |
| 2002 | 0.5689 | 0.1247 | 0.3275 | 0.7814 | 0.0153 | 0.0021 | 0.0116 | 0.0200 |
| 2003 | | | | | 0.0140 | 0.0022 | 0.0103 | 0.0189 |

**Appendix 7. Young female pintail annual survival and recovery rates.**

| Female | Young | | 95% CI | | Young | | 95% CI | |
|---|---|---|---|---|---|---|---|---|
| Year | S | SE | Lower | Upper | f | SE | Lower | Upper |
| 1960 | 0.6273 | 0.0786 | 0.4656 | 0.7648 | 0.0509 | 0.0037 | 0.0441 | 0.0587 |
| 1961 | 0.3916 | 0.0705 | 0.2649 | 0.5348 | 0.0379 | 0.0041 | 0.0307 | 0.0468 |
| 1962 | 0.4907 | 0.0873 | 0.3269 | 0.6564 | 0.0384 | 0.0048 | 0.0301 | 0.0490 |
| 1963 | 0.4597 | 0.0642 | 0.3390 | 0.5853 | 0.0397 | 0.0041 | 0.0323 | 0.0486 |
| 1964 | 0.5124 | 0.0694 | 0.3787 | 0.6444 | 0.0472 | 0.0037 | 0.0405 | 0.0549 |
| 1965 | 0.5837 | 0.0634 | 0.4567 | 0.7005 | 0.0370 | 0.0030 | 0.0315 | 0.0434 |
| 1966 | 0.4579 | 0.0414 | 0.3786 | 0.5394 | 0.0463 | 0.0025 | 0.0416 | 0.0515 |
| 1967 | 0.5648 | 0.0496 | 0.4664 | 0.6584 | 0.0412 | 0.0021 | 0.0372 | 0.0455 |
| 1968 | 0.5110 | 0.0705 | 0.3755 | 0.6449 | 0.0339 | 0.0039 | 0.0270 | 0.0426 |
| 1969 | 0.5003 | 0.0512 | 0.4014 | 0.5993 | 0.0479 | 0.0031 | 0.0421 | 0.0543 |
| 1970 | 0.4547 | 0.0582 | 0.3448 | 0.5692 | 0.0560 | 0.0037 | 0.0492 | 0.0637 |
| 1971 | 0.6128 | 0.0780 | 0.4538 | 0.7510 | 0.0425 | 0.0035 | 0.0362 | 0.0498 |
| 1972 | 0.6525 | 0.0947 | 0.4529 | 0.8098 | 0.0446 | 0.0041 | 0.0372 | 0.0534 |
| 1973 | 0.4259 | 0.0764 | 0.2868 | 0.5779 | 0.0407 | 0.0045 | 0.0327 | 0.0505 |
| 1974 | 0.6831 | 0.0813 | 0.5080 | 0.8182 | 0.0396 | 0.0027 | 0.0346 | 0.0453 |
| 1975 | 0.5040 | 0.0647 | 0.3797 | 0.6278 | 0.0353 | 0.0030 | 0.0299 | 0.0416 |
| 1976 | 0.6612 | 0.0790 | 0.4944 | 0.7957 | 0.0433 | 0.0032 | 0.0374 | 0.0500 |
| 1977 | 0.6894 | 0.1047 | 0.4598 | 0.8526 | 0.0347 | 0.0037 | 0.0281 | 0.0427 |
| 1978 | 0.6035 | 0.0851 | 0.4312 | 0.7534 | 0.0362 | 0.0032 | 0.0304 | 0.0430 |
| 1979 | 0.6146 | 0.0809 | 0.4495 | 0.7570 | 0.0351 | 0.0025 | 0.0306 | 0.0403 |
| 1980 | 1.0000 | 0.0001 | 0.0008 | 1.0000 | 0.0335 | 0.0037 | 0.0269 | 0.0416 |
| 1981 | 0.5859 | 0.1151 | 0.3583 | 0.7819 | 0.0343 | 0.0048 | 0.0260 | 0.0451 |
| 1982 | 0.8214 | 0.1540 | 0.3700 | 0.9730 | 0.0283 | 0.0042 | 0.0211 | 0.0378 |
| 1983 | 0.5828 | 0.0985 | 0.3871 | 0.7556 | 0.0396 | 0.0035 | 0.0332 | 0.0471 |
| 1984 | 0.8565 | 0.1956 | 0.2088 | 0.9926 | 0.0380 | 0.0046 | 0.0301 | 0.0481 |
| 1985 | 0.5096 | 0.1078 | 0.3085 | 0.7077 | 0.0288 | 0.0038 | 0.0221 | 0.0373 |
| 1986 | 0.7377 | 0.1335 | 0.4211 | 0.9158 | 0.0265 | 0.0030 | 0.0211 | 0.0331 |
| 1987 | 0.8936 | 0.2102 | 0.0992 | 0.9984 | 0.0219 | 0.0037 | 0.0157 | 0.0304 |
| 1988 | 0.6538 | 0.1883 | 0.2699 | 0.9061 | 0.0145 | 0.0043 | 0.0080 | 0.0259 |
| 1989 | 0.6713 | 0.1630 | 0.3244 | 0.8968 | 0.0249 | 0.0040 | 0.0181 | 0.0341 |
| 1990 | 0.6482 | 0.1536 | 0.3298 | 0.8734 | 0.0159 | 0.0027 | 0.0113 | 0.0223 |
| 1991 | 0.7683 | 0.1553 | 0.3750 | 0.9482 | 0.0207 | 0.0034 | 0.0149 | 0.0285 |
| 1992 | 0.4563 | 0.0930 | 0.2871 | 0.6363 | 0.0279 | 0.0035 | 0.0218 | 0.0358 |
| 1993 | 0.4784 | 0.0829 | 0.3235 | 0.6376 | 0.0236 | 0.0030 | 0.0184 | 0.0301 |
| 1994 | 0.5868 | 0.0835 | 0.4196 | 0.7361 | 0.0212 | 0.0023 | 0.0171 | 0.0262 |
| 1995 | 0.6879 | 0.1015 | 0.4659 | 0.8478 | 0.0339 | 0.0034 | 0.0279 | 0.0411 |
| 1996 | 0.6219 | 0.0934 | 0.4303 | 0.7818 | 0.0266 | 0.0031 | 0.0212 | 0.0333 |
| 1997 | 0.6557 | 0.0717 | 0.5054 | 0.7802 | 0.0382 | 0.0026 | 0.0334 | 0.0437 |
| 1998 | 0.4730 | 0.0691 | 0.3427 | 0.6070 | 0.0413 | 0.0039 | 0.0343 | 0.0495 |
| 1999 | 0.5934 | 0.0916 | 0.4094 | 0.7544 | 0.0533 | 0.0045 | 0.0451 | 0.0629 |
| 2000 | 0.6991 | 0.1267 | 0.4164 | 0.8832 | 0.0538 | 0.0051 | 0.0446 | 0.0647 |
| 2001 | 0.8057 | 0.1689 | 0.3334 | 0.9717 | 0.0557 | 0.0052 | 0.0464 | 0.0667 |
| 2002 | 0.5795 | 0.1740 | 0.2537 | 0.8481 | 0.0486 | 0.0050 | 0.0397 | 0.0594 |
| 2003 | | | | | 0.0382 | 0.0032 | 0.0324 | 0.0450 |

**Appendix 8. Central flyway total pintail harvest and harvest regulations from 1979-2003.**

| Year | Harvest | HIP | SIS | Days | Bag | DaysBag | MWS |
|---|---|---|---|---|---|---|---|
| 1979 | 228947 | 0 | 0 | 60 | 10 | 600 | 1697720 |
| 1980 | 193244 | 0 | 0 | 60 | 10 | 600 | 1542961 |
| 1981 | 151023 | 0 | 0 | 60 | 10 | 600 | 349677 |
| 1982 | 158994 | 0 | 0 | 60 | 10 | 600 | 617876 |
| 1983 | 139077 | 0 | 0 | 60 | 10 | 600 | 353175 |
| 1984 | 165804 | 0 | 0 | 60 | 10 | 600 | 593311 |
| 1985 | 83914 | 0 | 0 | 50 | 3 | 150 | 571800 |
| 1986 | 72071 | 0 | 0 | 51 | 3 | 153 | 335335 |
| 1987 | 122420 | 0 | 0 | 51 | 3 | 153 | 516825 |
| 1988 | 36387 | 0 | 0 | 39 | 1 | 39 | 733405 |
| 1989 | 43594 | 0 | 0 | 39 | 1 | 39 | 278559 |
| 1990 | 43206 | 0 | 0 | 39 | 1 | 39 | 589250 |
| 1991 | 28687 | 0 | 0 | 39 | 1 | 39 | 97190 |
| 1992 | 32095 | 0 | 0 | 39 | 1 | 39 | 905320 |
| 1993 | 42274 | 0 | 0 | 39 | 1 | 39 | 319120 |
| 1994 | 61456 | 0 | 0 | 49 | 1 | 49 | 431924 |
| 1995 | 94840 | 0 | 0 | 60 | 1 | 60 | 721753 |
| 1996 | 96634 | 0 | 0 | 60 | 1 | 60 | 317173 |
| 1997 | 189211 | 0 | 0 | 74 | 3 | 222 | 505419 |
| 1998 | 124994 | 0 | 0 | 74 | 1 | 74 | 612712 |
| 1999 | 138397 | 0 | 0 | 74 | 1 | 74 | 992064 |
| 2000 | 136592 | 0 | 0 | 74 | 1 | 74 | 374407 |
| 2001 | 151917 | 0 | 0 | 74 | 1 | 74 | 327797 |
| 1999 | 133317 | 1 | 0 | 74 | 1 | 74 | 992064 |
| 2000 | 134252 | 1 | 0 | 74 | 1 | 74 | 374407 |
| 2001 | 134612 | 1 | 0 | 74 | 1 | 74 | 327797 |
| 2002 | 60407 | 1 | 1 | 39 | 1 | 39 | 492311 |
| 2003 | 55641 | 1 | 1 | 39 | 1 | 39 | 713071 |
| 2004 | | | | | | | 664003 |

[1] HIP = data collected under the HIP program, SIS = years when seasons within a season (partial season) were adopted in the Central Flyway, and MWS is the Midwinter Survey population estimate from the Central flyway.

**Appendix 9. Atlantic flyway total pintail harvest and harvest regulations from 1979-2003.**

| Year | Harvest | HIP | SIS | Days | Bag | DaysBag | MWS |
|---|---|---|---|---|---|---|---|
| 1979 | 48462 | 0 | 0 | 50 | 4 | 200 | 72071 |
| 1980 | 38869 | 0 | 0 | 50 | 4 | 200 | 54492 |
| 1981 | 27891 | 0 | 0 | 50 | 4 | 200 | 67962 |
| 1982 | 38632 | 0 | 0 | 50 | 5 | 250 | 68900 |
| 1983 | 18636 | 0 | 0 | 50 | 5 | 250 | 48100 |
| 1984 | 34658 | 0 | 0 | 50 | 5 | 250 | 46200 |
| 1985 | 21685 | 0 | 0 | 40 | 2 | 80 | 34000 |
| 1986 | 19033 | 0 | 0 | 40 | 2 | 80 | 47400 |
| 1987 | 15788 | 0 | 0 | 40 | 1 | 40 | 36900 |
| 1988 | 7447 | 0 | 0 | 30 | 1 | 30 | 36235 |
| 1989 | 14588 | 0 | 0 | 30 | 1 | 30 | 55093 |
| 1990 | 10493 | 0 | 0 | 30 | 1 | 30 | 43995 |
| 1991 | 14201 | 0 | 0 | 30 | 1 | 30 | 68937 |
| 1992 | 12470 | 0 | 0 | 30 | 1 | 30 | 42705 |
| 1993 | 12923 | 0 | 0 | 30 | 1 | 30 | 51374 |
| 1994 | 18340 | 0 | 0 | 40 | 1 | 40 | 61510 |
| 1995 | 33163 | 0 | 0 | 50 | 1 | 50 | 50626 |
| 1996 | 19270 | 0 | 0 | 50 | 1 | 50 | 34606 |
| 1997 | 24010 | 0 | 0 | 60 | 3 | 180 | 43165 |
| 1998 | 33594 | 0 | 0 | 60 | 1 | 60 | 45419 |
| 1999 | 29527 | 0 | 0 | 60 | 1 | 60 | 65259 |
| 2000 | 22384 | 0 | 0 | 60 | 1 | 60 | 37890 |
| 2001 | 19950 | 0 | 0 | 60 | 1 | 60 | 47902 |
| 1999 | 25200 | 1 | 0 | 60 | 1 | 60 | 65259 |
| 2000 | 20752 | 1 | 0 | 60 | 1 | 60 | 37890 |
| 2001 | 19276 | 1 | 0 | 60 | 1 | 60 | 47902 |
| 2002 | 17089 | 1 | 1 | 30 | 1 | 30 | 48139 |
| 2003 | 18134 | 1 | 1 | 30 | 1 | 30 | 36324 |
| 2004 | | | | | | | 55523 |

[1] HIP = data collected under the HIP program, SIS = years when seasons within a season (partial season) were adopted in the Atlantic Flyway, and MWS is the Midwinter Survey population estimate from the Atlantic flyway.

**Appendix 10. Mississippi flyway total pintail harvest and harvest regulations from 1979-2003.**

| Year | Harvest | HIP | SIS | Days | Bag | DaysBag | MWS |
|---|---|---|---|---|---|---|---|
| 1979 | 213601 | 0 | 0 | 50 | 10 | 500 | 792000 |
| 1980 | 215811 | 0 | 0 | 50 | 10 | 500 | 324025 |
| 1981 | 207864 | 0 | 0 | 50 | 10 | 500 | 699575 |
| 1982 | 126568 | 0 | 0 | 50 | 10 | 500 | 886500 |
| 1983 | 187365 | 0 | 0 | 50 | 10 | 500 | 944975 |
| 1984 | 153680 | 0 | 0 | 50 | 10 | 500 | 532475 |
| 1985 | 124920 | 0 | 0 | 40 | 3 | 120 | 694300 |
| 1986 | 90350 | 0 | 0 | 40 | 3 | 120 | 422675 |
| 1987 | 88305 | 0 | 0 | 40 | 3 | 120 | 250075 |
| 1988 | 39225 | 0 | 0 | 30 | 1 | 30 | 452675 |
| 1989 | 65055 | 0 | 0 | 30 | 1 | 30 | 529275 |
| 1990 | 49487 | 0 | 0 | 30 | 1 | 30 | 650524 |
| 1991 | 40319 | 0 | 0 | 30 | 1 | 30 | 799597 |
| 1992 | 56520 | 0 | 0 | 30 | 1 | 30 | 518954 |
| 1993 | 52635 | 0 | 0 | 30 | 1 | 30 | 202043 |
| 1994 | 81147 | 0 | 0 | 40 | 1 | 40 | 537674 |
| 1995 | 136099 | 0 | 0 | 50 | 1 | 50 | 522198 |
| 1996 | 123817 | 0 | 0 | 50 | 1 | 50 | 631666 |
| 1997 | 144758 | 0 | 0 | 60 | 3 | 180 | 259594 |
| 1998 | 176990 | 0 | 0 | 60 | 1 | 60 | 378870 |
| 1999 | 167666 | 0 | 0 | 60 | 1 | 60 | 316760 |
| 2000 | 161476 | 0 | 0 | 60 | 1 | 60 | 486406 |
| 2001 | 130894 | 0 | 0 | 60 | 1 | 60 | 1207671 |
| 1999 | 148299 | 1 | 0 | 60 | 1 | 60 | 316760 |
| 2000 | 155082 | 1 | 0 | 60 | 1 | 60 | 486406 |
| 2001 | 122522 | 1 | 0 | 60 | 1 | 60 | 1207671 |
| 2002 | 102481 | 1 | 1 | 30 | 1 | 30 | 417918 |
| 2003 | 119005 | 1 | 1 | 30 | 1 | 30 | 248678 |
| 2004 | | | | | | | 572324 |

[1] HIP = data collected under the HIP program, SIS = years when seasons within a season (partial season) were adopted in the Mississippi Flyway, and MWS is the Midwinter Survey population estimate from the Mississippi flyway.

**Appendix 11. Pacific flyway total pintail harvest and harvest regulations from 1979-2003.**

| Year | Harvest | HIP | SIS | Days | Bag | DaysBag | MWS |
|---|---|---|---|---|---|---|---|
| 1979 | 829302 | 0 | 0 | 93 | 7 | 651 | 3265814 |
| 1980 | 633307 | 0 | 0 | 93 | 7 | 651 | 4015739 |
| 1981 | 403865 | 0 | 0 | 93 | 7 | 651 | 2508739 |
| 1982 | 467575 | 0 | 0 | 93 | 7 | 651 | 1831832 |
| 1983 | 465088 | 0 | 0 | 93 | 7 | 651 | 1181335 |
| 1984 | 312488 | 0 | 0 | 93 | 5 | 465 | 2411716 |
| 1985 | 292708 | 0 | 0 | 79 | 5 | 395 | 859305 |
| 1986 | 274953 | 0 | 0 | 79 | 4 | 316 | 1254794 |
| 1987 | 311406 | 0 | 0 | 79 | 4 | 316 | 663212 |
| 1988 | 116304 | 0 | 0 | 59 | 1 | 59 | 1262689 |
| 1989 | 139507 | 0 | 0 | 59 | 1 | 59 | 685403 |
| 1990 | 133154 | 0 | 0 | 59 | 1 | 59 | 888876 |
| 1991 | 126404 | 0 | 0 | 59 | 1 | 59 | 1051819 |
| 1992 | 116312 | 0 | 0 | 59 | 1 | 59 | 773548 |
| 1993 | 140895 | 0 | 0 | 59 | 1 | 59 | 741120 |
| 1994 | 150376 | 0 | 0 | 69 | 1 | 69 | 1055970 |
| 1995 | 258506 | 0 | 0 | 93 | 2 | 186 | 1012086 |
| 1996 | 280743 | 0 | 0 | 93 | 2 | 186 | 1435296 |
| 1997 | 338312 | 0 | 0 | 107 | 3 | 321 | 962026 |
| 1998 | 237276 | 0 | 0 | 107 | 1 | 107 | 1278494 |
| 1999 | 191994 | 0 | 0 | 107 | 1 | 107 | 1129553 |
| 2000 | 159242 | 0 | 0 | 107 | 1 | 107 | 1444171 |
| 2001 | 133307 | 0 | 0 | 107 | 1 | 107 | 1710149 |
| 1999 | 221850 | 1 | 0 | 107 | 1 | 107 | 1129553 |
| 2000 | 183950 | 1 | 0 | 107 | 1 | 107 | 1444171 |
| 2001 | 146169 | 1 | 0 | 107 | 1 | 107 | 1710149 |
| 2002 | 132151 | 1 | 1 | 60 | 1 | 60 | 1081216 |
| 2003 | 134936 | 1 | 1 | 60 | 1 | 60 | 1139062 |
| 2004 | | | | | | | 1219077 |

[1] HIP = data collected under the HIP program, SIS = years when seasons within a season (partial season) were adopted in the Pacific Flyway, and MWS is the Midwinter Survey population estimate from the Pacific flyway.

**Appendix 12. Continental pintail harvest, 1979-2003.**

| Year | PF | CF | MF | AF | AK | Canada | AK/Can | Total |
|---|---|---|---|---|---|---|---|---|
| 1979 | 829302 | 228947 | 213601 | 48462 | 16315 | 145609 | 161925 | 1482237 |
| 1980 | 633307 | 193244 | 215811 | 38869 | 23896 | 128762 | 152660 | 1233890 |
| 1981 | 403865 | 151023 | 207864 | 27891 | 18105 | 110980 | 129087 | 919728 |
| 1982 | 467575 | 158994 | 126568 | 38632 | 11755 | 104790 | 116546 | 908313 |
| 1983 | 465088 | 139077 | 187365 | 18636 | 13206 | 101784 | 114991 | 925156 |
| 1984 | 312488 | 165804 | 153680 | 34658 | 16465 | 103407 | 119873 | 786503 |
| 1985 | 292708 | 83914 | 124920 | 21685 | 13341 | 91099 | 104441 | 627667 |
| 1986 | 274953 | 72071 | 90350 | 19033 | 13061 | 59979 | 73041 | 529448 |
| 1987 | 311406 | 122420 | 88305 | 15788 | 10600 | 67172 | 77774 | 615690 |
| 1988 | 116304 | 36387 | 39225 | 7447 | 10509 | 69346 | 79858 | 279218 |
| 1989 | 139507 | 43594 | 65055 | 14588 | 11080 | 62947 | 74028 | 336771 |
| 1990 | 133154 | 43206 | 49487 | 10493 | 10284 | 71624 | 81909 | 318248 |
| 1991 | 126404 | 28687 | 40319 | 14201 | 6518 | 35212 | 41731 | 251342 |
| 1992 | 116312 | 32095 | 56520 | 12470 | 10613 | 33408 | 44022 | 261418 |
| 1993 | 140895 | 42274 | 52635 | 12923 | 4966 | 37741 | 41972 | 291434 |
| 1994 | 150376 | 61456 | 81147 | 18340 | 5087 | 44431 | 49782 | 360837 |
| 1995 | 258506 | 94840 | 136099 | 33163 | 8766 | 44299 | 52957 | 575673 |
| 1996 | 280743 | 96634 | 123817 | 19270 | 13641 | 52689 | 65007 | 586793 |
| 1997 | 338312 | 189211 | 144758 | 24010 | 10310 | 60750 | 71067 | 767350 |
| 1998 | 237276 | 124994 | 176990 | 33594 | 12984 | 59843 | 72828 | 645681 |
| 1999 | 191994 | 138397 | 167666 | 29527 | 10283 | 55683 | -- | -- |
| 2000 | 159242 | 136592 | 161476 | 22384 | 16856 | 58339 | -- | -- |
| 2001 | 133307 | 151917 | 130894 | 19950 | 9277 | 39643 | -- | -- |
| 1999 | 221850 | 133317 | 148299 | 25200 | 10854 | 55683 | 66537 | 595203 |
| 2000 | 183950 | 134252 | 155082 | 20752 | 17213 | 58339 | 75552 | 569589 |
| 2001 | 146169 | 134612 | 122522 | 19276 | 11306 | 39643 | 50949 | 473528 |
| 2002 | 132151 | 60407 | 102481 | 17089 | 11281 | 57028 | 68309 | 380437 |
| 2003 | 134936 | 55641 | 119005 | 18134 | 9084 | 47950 | 57034 | 384750 |
| 2004 | | | | | | | | |

Notes: (1) Data above the line use U.S. harvest estimates from the MQS, data below the line use estimates from HIP. (2) In years when both MQS and HIP estimates were available, only the HIP estimates were used to calculate totals.