Framework-Date Extensions
and the
Adaptive Management of Mallard Harvests

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Introduction

The U.S. Fish and Wildlife Service (USFWS) regulates the earliest opening and latest closing dates that States may use to establish duck-hunting seasons. These "framework dates" traditionally have centered around October 1 and January 20. The possibility of extending these dates so that seasons could open earlier and remain open later has been the subject of extensive and contentious debate within the management community. The controversy has stemmed from concern over potentially substantive increases in harvest, shifts in the distribution of harvest toward more northerly and southerly States, and possible deleterious effects due to changes in duck reproductive behavior or physiology. The magnitude of these effects remains largely speculative because there has been no experience with extended framework dates at a national level.

Despite this uncertainty, interest in extended framework dates remains strong among most southern and some northern States. In deference to this interest, the USFWS has agreed to propose an opening date of the Saturday nearest September 24 and a closing date of the last Sunday in January, with no reductions in season length, in the "liberal" and "moderate" regulatory alternatives. However, the USFWS has made it clear that such changes should be made within the context of adaptive harvest management (AHM). Specifically, the USFWS is interested in ensuring that the optimization of regulatory choices appropriately accounts for the uncertainty about the impacts of extended framework dates on mallard harvests, and in reducing this uncertainty to the extent possible through the AHM process.

The purpose of this document, therefore, is to propose a theoretical construct for accommodating framework-date extensions within the structure of AHM. This document also demonstrates how this theory would be applied to the existing AHM protocols for midcontinent and eastern mallards. This document does not, however, address possible changes in the distribution of harvest, behavioral or physiological effects, or impacts on species other than mallards.

Theoretical Framework

Prior Beliefs About Harvest Rates Under Current Regulatory Alternatives

When AHM was first implemented in 1995, three regulatory alternatives characterized as liberal, moderate, and restrictive were defined based on regulations used during 1979-84, 1985-87, and 1988-93, respectively. In 1997, the regulatory alternatives were modified to include (among other things) the addition of a very restrictive alternative, and additional days and a higher bag-limit in the moderate and liberal alternatives (USFWS 2001). Unfortunately, there was no experience with some of the new season-length and bag-limit combinations that would have provided for empirical estimates of mallard harvest rates. Therefore, harvest rates were predicted using harvest-rate estimates from 1979-84, which were adjusted to reflect the new specification of season lengths and bag limits, and for contemporary numbers of hunters. These predictions relied on models of hunting effort and success derived from hunter surveys (USFWS 2001:36-39), and on the critical assumption that changes in harvest rate are proportional to changes in harvest.

Updating Prior Beliefs

We propose to adopt Bayesian methods (Wade 2000) for updating our prior beliefs (i.e., predictions) about harvest rates associated with various regulatory alternatives (including those with framework-date extensions). Essentially, the idea is to use relevant prior information to develop initial harvest-rate predictions (e.g., as above), to make regulatory decisions based on those predictions, and then to observe realized harvest rates. Those observed harvest rates, in turn, are treated as new sources of information for calculating updated (posterior) predictions. Bayesian methods are attractive because they provide a quantitative and formal, yet intuitive, framework with which to express an adaptive approach to management (Ellison 1996).

We begin by specifying the following model structure:

$$
\begin{aligned}
&\textit{data}: \quad y_t \sim Normal(h_t, \sigma_t^2) \\
&\textit{truth}: \quad h_t \sim Normal(\mu, v^2)
\end{aligned}
$$

In this model, y_t represents an estimate (with sampling variance σ^2) of the annual harvest rate h_t under a given regulatory alternative. In turn, we assume that h_t is drawn from a normal distribution with mean μ and process error v^2. The process error represents the amount of variability in harvest rates under the same regulatory alternative due to annual variation in weather, habitat conditions, timing of migration, etc.

The problem is to estimate μ and v^2, given our prior beliefs about these parameters and any estimates of harvest rates y_t that become available from subsequent experience. To do this, we must first specify prior distributions for the parameters μ and v^2. These distributions represent a quantitative statement of our prior beliefs about the mean and variance of the harvest rate expected under a given regulatory alternative. For the prior distribution of μ, we suggest:

$$\mu \sim Normal\left(\theta, \frac{\nu^2}{n}\right)$$

where

$$\nu^2 = (\theta \times 0.2)^2$$
$$n = 6$$

The parameter θ must be specified for each regulatory alternative. We propose to use the predicted mean harvest rates derived from the procedures described in the previous section (USFWS 2001:13-14). That same procedure, however, provides only a combined estimate of $\nu^2 + \sigma^2$, which is not useful for our purpose. Therefore, we rely on information provided by Johnson et al. (1997), who estimate that ν is typically about 20% of the mean (i.e., CV = 0.2). We set $n = 6$ to reflect the empirical estimates of harvest rate during 1979-84 that were used to help derive initial predictions under the current regulatory alternatives.

Based on theoretical considerations, we suggest a scaled inverse gamma with n degrees of freedom and scale parameter ν^2 for the prior distribution of ν^2:

$$\nu^2 \sim Inverse\ Gamma\left(n, (\theta \times 0.2)^2\right)$$

Once prior distributions are fully specified for each regulatory alternative, they can be updated using estimates of harvest rates (based on band-recovery data) that become available after a particular regulatory alternative is implemented. Using standard Bayesian methodology, these prior distributions are converted to posterior distributions, from which sample posterior means and variances are derived. These posterior means and variances provide updated measures of μ and ν^2, which are used for predictive purposes in the next cycle of regulation-setting.

The Marginal Effect of Framework-Date Extensions

Next, we need to modify the model structure to account for the marginal effect of framework-date extensions:

$$h_t' \sim Normal\left(\mu + \Delta, \nu^2\right)$$

where Δ is the absolute change in mean harvest rate. In this model we assume that the process error remains unaffected, although we recognize it could be expected to increase with a framework-date extension.

As before, a key question is what to use as a prior distribution for the parameter Δ. We suggest:

$$\Delta \sim Normal\left(\theta \times \rho,\ \phi^2\right)$$

where ρ is the expected proportional change in mean harvest rate, and the variance ϕ^2 is a measure of uncertainty about ($\theta \times \rho$). A previous assessment suggests that $\rho = 0.15$ for midcontinent mallards and $\rho \leq 0.05$ for eastern mallards (USFWS 2000*b*). In the absence of other relevant assessments, we suggest these values be adopted for making initial predictions about the effects of framework-date extensions. Specifying ϕ^2 is more difficult because information provided by USFWS (2000*b*) is based on two critical assumptions: (1) that changes in harvest rate are proportional to changes in harvest; and (2) that past experience with an early opening date in Iowa and a late closing date in Mississippi accurately reflects the expected effect in other States where extensions have never been offered. Because of the tenuousness of these assumptions, we suggest that variance estimates presented by USFWS (2000*b*) does not adequately characterize the level of uncertainty about Δ. Therefore, we suggest values of ϕ^2 that bound the lower 95% confidence limit for ($\theta \times \rho$) by zero. This would be an explicit recognition that our prior beliefs include the possibility that $\Delta = 0$. Although some might propose even larger values of ϕ^2, all harvest managers we have asked believe strongly that $\Delta > 0$.

If and when framework-date extensions are implemented, estimates of harvest rate derived from band-recovery data would be used to update the prior distribution for Δ. We should recognize, however, that any inference about the causal relationship between Δ and framework extensions will be very weak because changes due to extensions will be confounded with any other uncontrolled changes in harvest rates (i.e., there will be no experimental controls).

Application - Midcontinent Mallards

We here demonstrate application of the Bayesian methods described above for predicting harvest rates of midcontinent mallards. We first describe an updating of the prior distributions of the parameters in our harvest-rate model for the current liberal regulatory alternative, and then propose prior distributions for the moderate alternative and for the marginal effect of framework-date extensions.

Based on previous analyses (USFWS 2001) and on assumptions described previously, we first specify prior distributions for μ and ν^2 under the liberal regulatory alternative:

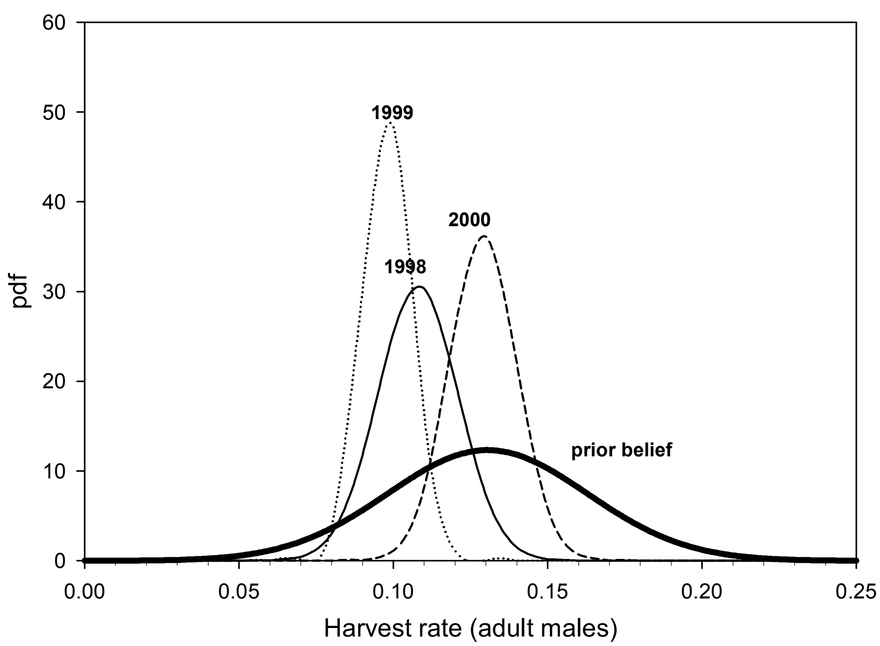
$$\mu \sim Normal\left(0.1305,\ \frac{0.0261^2}{6}\right)$$

$$\nu^2 \sim Inverse\ Gamma\left(6,\ 0.0261^2\right)$$

We currently have three years of harvest-rate estimates under the liberal alternative (a fourth estimate likely will be available later this year). Reward banding in banding reference areas 2, 4, and 5 provided the basis for these estimates (USFWS 2001:40). Harvest rates in un-sampled reference areas were treated as missing, and conventional data augmentation techniques were used. Estimates of harvest rate were first computed for each reference area, and then these estimates were averaged using breeding-population estimates in each reference area as weights. This procedure resulted in the following estimates:

$$y_{1998} = 0.108\ (\sigma^2 = 0.013^2)$$
$$y_{1999} = 0.098\ (\sigma^2 = 0.008^2)$$
$$y_{2000} = 0.129\ (\sigma^2 = 0.011^2)$$

These estimates are compared with prior beliefs about liberal harvest rates in the following figure.



Combining our prior distributions and harvest-rate estimates, we calculated posterior (updated) means and standard deviations for the following parameters of interest:

$$h_{1998} = 0.112\ \ (\mathrm{SD} = 0.0111)$$
$$h_{1999} = 0.101\ \ (\mathrm{SD} = 0.0076)$$
$$h_{2000} = 0.128\ \ (\mathrm{SD} = 0.0097)$$
$$\mu = 0.123\ \ (\mathrm{SD} = 0.0087)$$
$$\nu^2 = 0.0005\ \ (\mathrm{SD} = 0.00036)$$

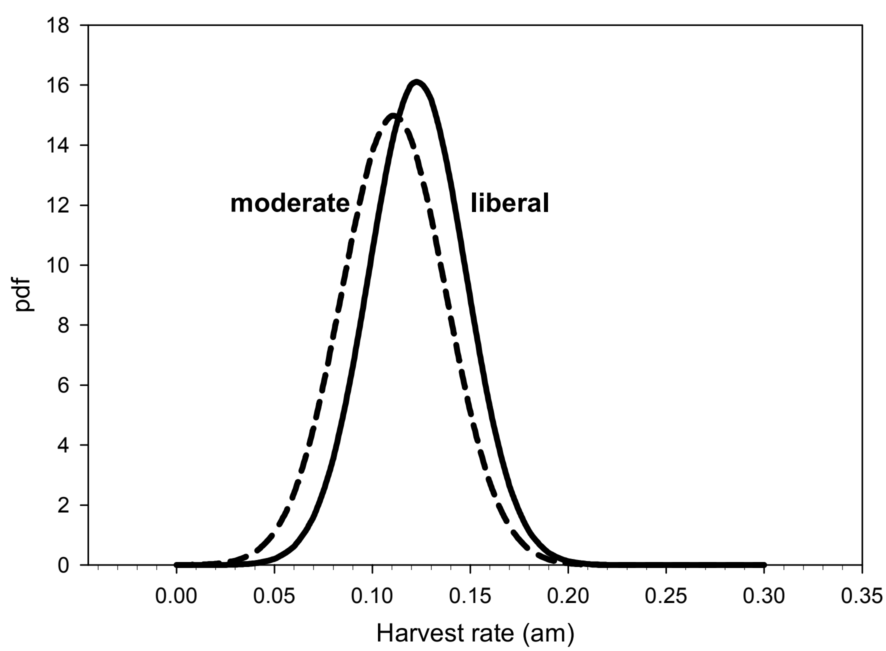
Thus, our best estimate of the mean harvest rate (μ) under the liberal regulatory alternative decreased from 0.130 to 0.123 to become more consistent with the three years of observation. Also, the estimate of process error (v^2) decreased to reflect the relatively low variability in harvest rates observed among years.

Shifting our attention now to the moderate regulatory alternative, we propose the following prior distributions:

$$\mu \sim Normal\left(0.111, \frac{0.0222^2}{6}\right)$$

$$v^2 \sim Inverse\ Gamma\left(6, 0.0222^2\right)$$

Unfortunately, we have no experience with which to update our prior beliefs about harvest rates under the moderate regulatory alternative. This concerns us because updated predictions of harvest rates under the liberal alternative vary little from the prior beliefs about the moderate alternative (see figure below). The lack of substantive differences in predicted harvest rates among regulatory alternatives can precipitate so-called knife-edge harvest strategies, in which small changes in resource status can precipitate large changes in the prescribed regulatory alternative.



We next anticipate the effect of framework-date extensions under the liberal alternative with a proposed prior distribution for Δ:

$$\Delta \sim Normal\left(0.02,\, 0.01^2\right)$$

The mean of this distribution was based on a predicted 15% increase in mean harvest rate (USFWS 2000*b*), and the variance was specified subjectively to provide a 95% confidence interval on Δ of 0.00-0.04. A value of 0.01^2 for the variance reflects *a lot* of prior uncertainty about the magnitude of Δ. We propose to add this variance to the process error (ν^2) for the purpose of optimizing regulatory choices; this will ensure that prescribed regulatory choices properly reflect uncertainty about the effects of framework-date extensions.

Parameters of the prior distribution for Δ will be updated after experience with extensions in the liberal alternative. The fixed prior distributions for μ, ν^2, and Δ, together with harvest-rate estimates from years of the liberal alternative without (1998-2001) and with extensions, will be used to generate posterior distributions for all model parameters.

Framework-date extensions under the moderate regulatory alternative are more problematic. To date, we have no experience with the moderate alternative without framework-date extensions. Unless this changes, any posterior estimates of Δ would depend *only* on our *prior* beliefs about moderate harvest rates without extensions. For example, if μ under the current moderate alternative is actually less than that suggested by our prior beliefs (as was the case with the liberal alternative), then the estimated marginal effect of a framework-date extension in the moderate alternative would be biased low. In any case, using rationale analogous to that for the liberal alternative, we suggest the following prior for Δ under the moderate alternative:

$$\Delta \sim Normal\left(0.017,\, 0.009^2\right)$$

Application - Eastern Mallards

We here propose prior distributions for harvest rates of eastern mallards under the current moderate and liberal regulatory alternatives, and discuss issues involved in modeling the effect of framework-date extensions.

Unlike the case with midcontinent mallards, no estimates of eastern-mallard harvest rates are available since 1997 because no reward banding has been conducted in eastern reference areas. Thus, we remain wholly dependent on prior beliefs about harvest rates under the current regulatory alternatives. Another complicating factor with eastern mallards is that harvest rates appear to be measurably affected by the regulatory choice in the three western Flyways, where regulations depend only on the status of midcontinent mallards (USFWS 2000*a*:14). To avoid making the regulatory choice in the Atlantic Flyway conditional on regulations elsewhere, USFWS predicts harvest rates of eastern mallards assuming managers lack *a priori* knowledge of the regulation chosen in the western three Flyways (USFWS 2001). This is done by taking a weighted average of the eastern-mallard harvest rates predicted for each of the possible regulatory alternatives in the western Flyways, for each possible regulatory alternative in the Atlantic Flyway. The weights were derived using simulations of the midcontinent-mallard harvest strategy to determine the expected frequency of regulatory choices in the western Flyways.

Using information provided by USFWS (2001) and assumptions described previously, we tentatively propose the following prior distributions for harvest rates under the current liberal regulatory alternative in the Atlantic Flyway:

$$\mu \sim Normal\left(0.176, \frac{0.0352^2}{6}\right)$$

$$v^2 \sim Inverse\ Gamma\left(6, 0.352^2\right)$$

For the moderate alternative, we suggest:

$$\mu \sim Normal\left(0.166, \frac{0.0332^2}{6}\right)$$

$$v^2 \sim Inverse\ Gamma\left(6, 0.0332^2\right)$$

We describe these proposed distributions as tentative because they are based on current predictions of the frequencies with which regulatory alternatives are prescribed in the three western Flyways. These predicted frequencies are expected to change when population models and associated weights for midcontinent mallards are revised as described by USFWS (2001:17-18). This task should be completed by April 2002.

With respect to framework-date extensions, we again suggest using information provided by USFWS (2000*b*) for the purpose of constructing a prior distribution for Δ for eastern mallards. That assessment suggests that the increase in eastern-mallard harvest would be about 5% if the moderate and liberal alternatives were in effect nationwide, 4% if the moderate or liberal alternative were in effect only in the western three Flyways, and about 2% if the moderate or liberal alternative were in effect only in the Atlantic Flyway. These estimates are comparable to those provided by the Atlantic Flyway Technical Section (2001) based on different methodology and assuming only a closing-date extension. We also suggest that the prior variance of Δ be specified in a manner similar to that proposed for midcontinent mallards. However, given prior information that suggests only minor increases in eastern-mallard harvest, it might be appropriate to admit a relatively large probability that Δ = 0 (e.g., bound the lower 68% confidence limit by zero).

Summary

(1) We propose to adopt Bayesian methods to structure an adaptive approach to framework-date extensions. The approach depends on the specification of prior beliefs, including the level of uncertainty (i.e., statistical distributions of relevant parameters), about regulation-specific harvest rates, both with and without extensions. These prior beliefs would be used initially to support a regulatory decision. After regulations were enacted, realized harvest rates would be estimated based on band-recovery data. These estimates would be combined with prior beliefs to determine posterior (updated) beliefs about regulation-specific harvest rates, which in turn would be used in the next cycle of regulation setting.

(2) Application of this approach to midcontinent mallards suggests that the mean and variance of harvest rates under the current liberal alternative are slightly less than originally predicted in 1997. The posterior prediction of harvest rates under the liberal alternative is very similar to the prior prediction for the moderate alternative, raising the level of concern about knife-edge harvest strategies. With regard to framework-date extensions, we suggest using information provided by USFWS (2000*b*) to help establish a prior distribution for the marginal effect on harvest rates. We propose that the mean of this prior distribution should reflect an expected 15% increase in harvest rate. However, the variance of this prior distribution should be large enough to reflect our collective level of uncertainty about the effect of framework-date extensions.

(3) Unlike the case with midcontinent mallards, no estimates of eastern-mallard harvest rates are available since 1997 because no reward banding has been conducted in eastern reference areas. Thus, we remain wholly dependent on prior beliefs about harvest rates under the current regulatory alternatives. Another complicating factor with eastern mallards is that harvest rates appear to be measurably affected by the regulatory choice in the three western Flyways, where regulations depend only on the status of midcontinent mallards. Therefore, to predict harvest rates of eastern mallards we depend on simulations to determine the expected frequency of regulations in the three western Flyways. We cannot produce the required estimates of these frequencies until population models and associated weights for midcontinent mallards are revised later this spring. For eastern mallards, we also suggest that information provided by USFWS (2000*b*) be used to establish prior beliefs about the marginal effect of framework-date extensions. Accordingly, we would expect an increase in mean harvest rate $\leq$5%. We also believe that we should consider a variance that admits a larger probability that the increase would be zero than that for midcontinent mallards.

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