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Adaptive Harvest Management Working Group

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ADAPTIVE HARVEST MANAGEMENT WORKING GROUP

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AHM Implementation: Status and Issues - *Fred Johnson*

The implementation of adaptive harvest management (AHM) is proceeding in two phases. Phase I involves the development of stochastic optimization procedures for harvest management, and the specification of regulatory alternatives, population models, and management objectives for midcontinent mallards. This phase has been largely completed, and is providing a comprehensive and coherent structure for informed decision making. The AHM process permits optimal decisions in the face of several sources of management uncertainty, while providing a clear linkage between management decisions and resource monitoring programs, and incorporating feedback mechanisms that are essential to learning. Phase I has not been without problems, however. Foremost among these have been instability in the set of regulatory alternatives, tacit disagreement over ancillary management objectives, and increased uncertainty about regulatory impacts on species other than mallards. Phase II is intended to build upon the AHM foundation for midcontinent mallards, by developing decision protocols for other mallard stocks and other duck species. Phase II also involves the exploration of actively adaptive harvest strategies, which involve a tradeoff between short-term management performance and the long-term value of understanding the impacts of hunting regulations and uncontrolled environmental factors on waterfowl populations.

Pacific Flyway Report - *Dan Yparraguirre, Tom Aldrich, and Bob Trost*

Jeff Herbert, who has been one of the Pacific Flyway representatives to the AHM Working Group since its inception, recently took another position with the Montana Department of Fish, Wildlife and Parks and will no longer serve on the Working Group. The Pacific Flyway will appoint his replacement in July, 1999. Tom Aldrich will fill in until then.

The Pacific Flyway Study Committee and Council remains supportive of AHM. At the March Flyway meeting, the Pacific Flyway Council did not take a formal position on the framework extension issue, but elected to have Council Chair Terry Mansfield work through the National Flyway Council to try to accommodate some flexibility in frameworks without increasing harvest or dramatically impacting the AHM process. The hunting public in the Pacific Flyway for the most part remains silent on AHM issues with the exception of the California Waterfowl Association, who recently published an article critical of AHM as being over-simplistic and insensitive to regional mallard populations.

The Pacific Flyway remains committed to developing model sets for "western" mallards and northern pintails, and incorporation of these stocks into AHM. Sue Shaffer will present a progress report on these two efforts later in this meeting. As part of the western mallard initiative, the Pacific Flyway will conduct an experimental breeding pair survey in a portion of British Columbia to get an idea of mallard breeding densities. British Columbia is believed to be a significant source of western mallards that currently is not surveyed in any systematic fashion.

Central Flyway Report - *Mike Johnson, Jim Gammonley, and Dave Sharp*

The Central Flyway (CF) remains committed to the AHM process. We appreciate the continued support and assistance of Jim Dubovsky with CF issues and activities. We believe that it is most beneficial to both the Office of Migratory Bird Management and the CF to have long-term involvement of members from both sides.

At our recent meeting in Lawton, Oklahoma we discussed ideas and issues relating to AHM. We would like to bring the following results of this discussion to the Working Group's attention. These are in no particular order of importance.

Framework issues.--Of course, we are fully aware of the problems during the past year with framework issues. We object to the methods used by the state of Mississippi and Congress to modify hunting seasons and the Council and member states provided comments to this effect several times. The CF supports earlier framework dates for northern states and does not support later framework dates for southern states. This position stems from recent teal season liberalizations granted to non-production states. It is also related to the need to increase the harvest of midcontinent light geese. We have also discussed prescriptive regulations for states versus options that would be available under the USFWS's preferred Flyway approach to setting regulation packages. With all of this in mind, the CF supports continuing packages from 1998 - or really, 1997.

Banding.--The CF is eager to get a Reward Band Study underway. This is a critical need for AHM. We are awaiting results from this past year. When are we going to get this study underway? When would we have results to help us understand harvest rates? We believe our current Banding Program should be useful for a reward band study. However, we note that 1999 will be the 4th year of our 6 year program. We have banded nearly 111,000 ducks in 4 states during the past 3 seasons, including over 47,000 mallards and over 45,000 blue-winged teal. This work is funded by CFC, USFWS, DU, ND, SD, MT, WY and other cooperators. The CF is also concerned about problems with the Bird Banding Lab. We have become aware of several band supply and quality problems which could seriously jeopardize results from banding for many species. We will be addressing this issue with letters from Council.

Data and models.--We do not understand fall age ratio data. We think we need to learn much more about how age ratios in the harvest relate to recruitment. We believe that recruitment models are poorly understood, especially relative to density dependence. We need to improve our efforts to measure recruitment. The CF would like to learn more about pintail AHM and we have been instructed to bring what we can back to the CF. We may ask other AHM work group members for assistance with this. We are concerned about the need to improve AHM models and their performance.

Regulations and packages.--We see problems with increased special bag limit regulations - we now have special regulations for pintails, canvasbacks, redheads, mottled ducks, black ducks, wood ducks, hooded mergansers and soon to be scaup. This is a concern to us and our sportsmen. We believe there are benefits to keeping regulations simple. We again discussed the issue of the narrow width of regulatory bands in the matrix. This working group has reviewed this issue in the past. We know there is nothing that can be done to change this short of reducing the number of packages. We had extensive discussions about the two hen bag limit. Some CF members are questioning if it was the right thing to do. If we had a one hen bag limit in the liberal package, would we have a higher probability of having liberal seasons? We also had extensive discussions about AHM models relative to drake and hen mallards.

AMAT and AHM.--The CF is still concerned that AMAT (USFWS Adaptive Management and Assessment Team) has reduced our ability to deal with AHM. We strongly support AMAT, but we do not believe that personnel and time should have been taken away from AHM to get AMAT underway. We are aware that the AMAT team met with the PPJV last fall, and we would like to learn more about how AMAT will work with and capitalize on the tremendous progress that the PPJV and the HAPET office have made in developing planning and evaluation products for the PPJV. CF would like a thorough review of AHM at one of its meetings. This past December, Paul Padding and Woody Martin spent a full day with us reviewing harvest surveys and the HIP (Harvest Information Program). This was very valuable. We look for a similar review of AHM from Fred Johnson and/or other members of the AHM/AMAT staff.

Scaup.--We are very concerned about the current scaup issue. We have produced a recommendation which we believe to be sound and in keeping with USFWS philosophy on this issue. However, we wish to reiterate that we do not believe hunting at its current level is a problem for scaup populations. We urge the USFWS to carefully consider this issue when discussing scaup with the public and to avoid unnecessary restrictions on scaup as much as possible. If restrictions are necessary, we believe that they should be made where and when they will be most effective (i.e. the Mississippi Flyway). In keeping with this philosophy we have discussed the possibility of special scaup regulations for Texas.

Finally, we are sorry to report that Joe Gabig no longer represents Nebraska on the Central Flyway Waterfowl Technical Committee. Joe was a tremendous asset to both our committee and the AHM Working Group. However, we are pleased that Dr. Jim Gammonley has been appointed as the new CFWTC representative to the AHM Working Group. We look forward to Jim's long-term involvement in the AHM process.

Mississippi Flyway Report - *Dale Humburg, Scott Baker, and Ken Gamble*

An AHM committee was established during 1998 to ensure continuity of experience gained by past AHM Working Group members, such as Ron Pritchert and Jeff Lawrence, and to ensure their on-going involvement. The committee is composed of past AHM Working Group members and the chairs of the Regulations Committees. This committee has been responsible for conducting AHM workshops with the Technical Section and Council.

Three aspects related to AHM regulations alternatives have been of concern to the Mississippi Flyway:

(1) clarification of the blank cells in the decision matrix;
(2) utility of the "very restrictive" option (20 days in the Mississippi Flyway); and
(3) the nature of annual changes in regulations.

These concerns remain unresolved; however, we believe attention will be needed to these issues before less than "optimal" decisions will be required. Our consensus was that guidelines on how we would proceed in the event of various regulations scenarios (related to the above concerns) would be consistent with the explicit nature of AHM. Deciding now that a suboptimal regulations decision would be likely under certain conditions (e.g. continued open seasons with mallard populations that historically supported hunting) is preferable to waiting until we are faced with both deteriorating resource status and difficult decisions in conflict with the optimal AHM decision.

During 1998-99, the primary focus involved priorities for AHM and potential impacts of frameworks extensions. In an effort to initiate dialogue about harvest management perceptions, we itemized terms that individuals believed were important in characterizing harvest management. Common (but undefined) terms included:

fair	allocation	biological sound
equitable	social issue	satisfaction
optimal	adaptive	reasonable
opportunity	harvest value	traditional distribution

Further, we itemized possible measures of the term, "equitable":

- dead ducks in the bag each day
- dead ducks in the bag for the season
- (equal) satisfaction
- days of opportunity
- no one gets more than me
- regulations in each region / state

Clearly there is a broad range of perceptions of harvest management. Future review/debate about management objectives should consider the range of views about terms and measures. Without clear definitions, management objectives have limited value.

Challenges for AHM, in light of the past years' debate about frameworks, have changed from priorities identified in 1997. We outlined some of the biological and technical challenges currently affecting duck harvest management in general and AHM specifically. We also were interested in the degree to which a framework extension, if offered, would be applied among states. These were the bases for discussions during an evening AHM workshop. Small working groups were comprised of states from different tiers of the flyway: (1) MN-WI-MI-IA; (2) MO-IL-IN-OH; (3) AR-TN-KY; and (4) LA-MS-AL. Small group discussions reflected the perceived value of an early or late extension and potential impacts on mid-continent mallards and selected other duck species or stocks. The importance of an extension and associated biological impacts were discussed in each small group and ranked. In summary (see table below) there was moderate interest in an early extension in the North, and none elsewhere. Late season interest was most apparent in the South, fairly high in the Mid-South, and limited in the mid-latitude states (e.g. Ohio River zones in Indiana and Ohio). Concerns about mallard impacts were the greatest in the North and Mid-South (for late extension), and from the South if early and late extensions were implemented nationwide. Great to moderate concerns were indicated for late-season black ducks, Great Lakes mallards, early-season wood ducks (TN and KY), and late season pintails.

Ranks of importance and potential biological impacts of frameworks extensions by region
(**1** = least important and **3** = greatest importance, range in parentheses)

Working group	Early	Late	MC-Mallard	Species #1	Species #2	Species #3
MN,WI,MI, IA	**2** (1-3)	NA	unk.	Great Lakes mallards **2** (1-3)	wood ducks = **1** (0-3)	ring-necked duck = **1**
MO,IL,IN,OH	-	**0.5** (0-3)	**0**	Black duck (**3**)	--	--
AR, KY, TN	**0**	**2.5**	Late - **2** early - **0**	wood ducks late = **1** early = **2.5**	pintail late = **2** early = **1**	black duck late = **3** early = **0**
LA,MS,AL	NA	**3**	**1** (**2** if nation-wide)	wood duck nesting females = **1**	mottled duck nesting females = **1**	

Potential consequences must be considered if frameworks extensions are incorporated into the AHM regulations package. Some primary consequences were itemized as follows:

- Change in distribution of harvest
- Assessment capability
- Waterfowl hunter support
- Loss of hunting opportunity, more time in restrictive seasons
- Ability to learn with AHM - population dynamics.
- Biological impacts
- Complicates the historic and biological regulations setting process

We evaluated the consequences of several framework extension proposals:

(1) "NFC proposal" - National Flyway Council during Fall 1999; an option of 5 days earlier and 5 days later that 1997-98 frameworks);
(2) "User-pays" -- frameworks extended to the Saturday nearest 23 September and to 31 January;

however, penalties in season length reduction commensurate with anticipated increase in harvest would occur in the states selecting the framework extension.

(3) "Everybody pays" --frameworks extended to the Saturday nearest 23 September and to 31 January; however, an overall reduction in season lengths among regulations options would offset the expected impact on mallard harvest.

(4) "Buy now-pay later" -- frameworks extended to the Saturday nearest 23 September and to 31 January with no penalty and no change in regulations options. Hypotheses of the potential impacts of framework extensions (e.g. no impact vs. 20% increase in harvest) would be incorporated into the AHM process to determine their impacts. Questions about whether these would be statewide or by zone and whether there would be state-specific penalties were discussed. Although not resolved, there was general recognition that as more options and complexity are added, the ability to evaluate impacts is reduced.

(5) "Status Quo" -- frameworks extensions limited to southern Mississippi Flyway as in 1998-99.

(6) "1997-98" -- small groups also were allowed to add another framework extension option for evaluation. The only other option offered was by the North and mid-latitude groups and included the same regulations as during 1997-98

Each group ranked the consequences (6=most severe consequence and 1=least severe consequence) within each of the five or six framework extension options. The result was a varied perspective both within and among regions. Consequences varied among frameworks options; but these perspectives were not necessarily shared among regions. For example, assessment concerns generally were greatest for options similar to 1998 ("status quo"), while "lost hunting opportunity was greatest for "everybody pays" or "buy now - pay later." When all options were combined, overall perspectives by region also were different. Biological concerns ranked highest for the MN-WI-MI-IA and AR-KY-TN groups, harvest distribution was a greater concern by MO-IL-IN-OH, and less learning was the primary overall concern for LA-MS-AL. Although assessment concerns were not ranked highest by any single group, this aspect ranked among the higher concerns overall. Following are combined scores for each consequence within regional group for all frameworks options combined (total score possible=30 for all groups except for the MN-WI-MI-IA Group which did not provide relative scores for "NFC"; thus, total possible=25):

Consequence	Regulations options				
	MN-WI-MI-IA	MO-IL-IN-OH	AR-KY-TN	LA-MS-AL	TOTAL
Harv distr.	12	25	5	18	60
Assessment	16	15	22	18	71
Hunter support	10	14	12	13	49
Lost hunt opport.	13	15	18	20	66
Less learning	14	20	20	23	77
Biological impact	19	16	28	13	76

Atlantic Flyway Report - *Bryan Swift, Gary Costanzo, and Jerry Serie*

Satisfaction with Current Regulatory Options.--The Atlantic Flyway Council and Technical Section recommended that no changes be made to the four regulatory options that have been in effect since 1997. Most states appreciate the additional recreation and harvest opportunity afforded by the current options (especially longer seasons and the 2-hen mallard limit), compared to the packages used previously. In fact, there is virtually no desire for longer seasons or higher bag limits for mallards or total ducks than the current liberal option. However, there is still some dissatisfaction with total bag limits, more for sociological than biological reasons. Most would prefer it to be the same as the mallard limit, as we recommended back in 1997. It is hard for many to accept more liberal regulations for diving ducks, and there are concerns that the additional harvest, although small, is not desirable. There is also some concern that the current season length, more than bag limits, may result in over harvest of some species other than mallards, although population trends have not indicated any problems. Despite these concerns, we felt that the need for changes was not so compelling that the packages should be changed at this time. We are concerned that changes would reduce our ability to learn from experiences of the past 2 years if the packages are not maintained for several more years. That said, we would likely support the elimination of the “very restrictive” package if it is determined that it we could get by without it.

Framework Dates.--As indicated above, we do not favor any changes to the current set of regulatory options, including framework dates of about October 1 and January 20. We are especially concerned about the potential for reduced frequency of liberal seasons as a result of framework extensions. This concern would be mitigated somewhat if Atlantic Flyway regulations were based primarily on eastern mallards, since very few are harvested in states where season extensions would most likely occur. The same may be true for black ducks, but there would be concern about potential for higher harvests of wood ducks.

The flyway notes that the greatest demand for framework extensions has come from states that already enjoy very high seasonal duck harvest per hunter. Therefore, if season extensions are offered to such states, they should be offered to all states. Furthermore, we feel that some compensation or adjustment in season length would be necessary if extensions are allowed, but that compensation should be state by state, not flyway wide. Reducing season lengths in the moderate and liberal packages, and not allowing extensions during restrictive seasons, in states selecting extended dates, would be appropriate. Although this would complicate prediction of harvest rates, most states in the Atlantic Flyway would vigorously oppose any across-the-board loss of opportunity to accommodate season extensions in a select group of states.

Integration of Eastern Mallards.--From the inception of this working group, the Atlantic Flyway’s primary goal has been the development of harvest strategies based on the status of eastern duck populations rather than mid-continent breeding birds. Fred Johnson has estimated that eastern mallards may be able to sustain liberal seasons 98% of the time, compared to 64% of the time for mid continent birds. The greater frequency of liberal seasons would be significant to our hunters.

We have only a single working model for eastern mallards that seems to perform well enough (and with little disagreement) so that we have had little basis or incentive to develop alternative models. On the other hand, we are anxious to formalize a procedure for integrating eastern and midcontinent mallards into a harvest strategy for the Atlantic Flyway. A weighted approach may be satisfactory, but with >80% (90% of females and juveniles) of the flyway harvest derived from eastern stocks, the benefit of a weighted versus single eastern-stock approach is unclear. Within the flyway, the proportion of eastern mallards in the harvest varies from 100% in New England to about 50% in the southernmost states, so some states would favor a single stock approach for the north and a mixed stock strategy for the south. Nonetheless, we would likely support any approach that reasonably reflects the contribution of eastern mallards in the flyway for the next several years.

AHM for Other Species.--Although we are generally satisfied with the status and progress regarding mallard harvest strategies, we have perhaps greater uncertainty, if not disagreement, about effects of harvest on black ducks and wood ducks in the Atlantic Flyway. If data bases are adequate, these species are ripe for application of AHM to determine appropriate season lengths and bag limits. We would strongly support efforts to apply AHM to those species. AHM for pintails or other species are of much lower priority; as pintails account for only 1.3% of our total duck harvest, and we suspect that we may harvest a subpopulation of eastern pintails that is not currently recognized. Canvasbacks have already been tested, and scaup may have similar problems with adequacy of data. Realistically, we should explore AHM only for species that account for a large proportion of the harvest and have extensive data bases. Prescriptive approaches will have to be used for other species even if harvest may be more conservative than necessary.

Modeling and Adaptive Management of American Black Duck Populations

- *Mike Conroy*

I reported on the completion of a project to develop an integrated modeling approach for summarizing our understanding of American black duck populations. A literature review suggested that there is at least some support for four major hypotheses:

(I) limitation of populations through losses in the quantity or quality of breeding habitats;
(II) limitation of populations through losses in the quantity or quality of wintering habitats;
(III) harvest limitation; and
(IV) competition from mallards during the breeding period, wintering/ migration period, or both.

These hypotheses were used as the basis of an annual life cycle model, in which reproduction rates and survival rates were modeled as functions of the above factors, with parameters of the model describing the strength of these relationships. We then used available, historical data on the black duck populations (abundance, annual reproduction rates, and survival rates) and possible driving factors (trends in breeding and wintering habitats, harvest rates, and abundance of mallards) to estimate model parameters. Our resulting "best fit" models included parameters describing positive influence of breeding habitat and negative influence of black duck and mallard densities on reproduction rates, and negative influence of both black duck density (indicating compensation to

harvest mortality) and mallard density (suggesting negative competitive effects) on survival rates. We used these parameter estimates to investigate the impacts of statistical uncertainty in parameter values on predicted population growth rates for the combined (annual) model, and the effects of variation combinations of factors (breeding habitat, harvest rates, and mallard densities) for fixed parameter values, on predicted growth rates, in an effort to understand how these factors might interact in determining population response. We used the combined model, together with our historical data set, to perform a series of one-year population forecasts, similar to those that might be performed under adaptive management, and to eight models, each associated with differing beliefs about the combined effects of breeding habitat (H), mallard populations (M), and harvest compensation (C). The two apparently best models were 000 (no habitat effect, no mallard effect, and additive response to harvest) and 0M0 (same as the previous but a negative mallard effect). The agreement of predictions under this model to observed indices to spring abundance was consistent over both the period over which parameter values were estimated (1961-1994) and recent years (1995-1997) independent of these estimates.
The completed project is now the basis for continued work to develop an adaptive harvest management strategy for American black ducks. The objectives of this project include:

(1) extension of the model to allow appropriate spatial or other stratification;
(2) development of an appropriate objective function), possibly including explicit linkage between a black duck objective and a "mallard objective;"
(3) identification of key system states requiring monitoring for feedback into adaptive decision making, and the spatial and temporal scales at which monitoring is needed;
(4) identification and clarification of goals and objectives of an adaptive management protocol; and
(5) identification of relevant units by which decisions (e.g., harvest) can or will be made.

This work will be conducted in close collaboration with a parallel project on the development of an AHM communication strategy for black ducks, and with efforts to develop a joint, international harvest management strategy for black ducks.

Estimating optimal waterfowl harvest decisions using the genetic algorithm - *Clinton T. Moore, Michael J. Conroy, Kevin Boston, and Walter D. Potter*

Management of many natural resource systems involves making recurring decisions through time or space. Decisions must be made with respect to both the future status of the resource and to the series of decisions to be made henceforth. Methods in optimal control theory, particularly dynamic programming (DP), have been used to find optimal decision sequences. By looking backwards through time, DP is able to very efficiently enumerate consequences of all decision actions for all system states of a Markovian system. Furthermore, DP accommodates problems of system stochasticity and structural uncertainty. DP has been put to successful use in many applications, including waterfowl harvest management (Johnson et al. 1997).

Because DP enumerates transitions among members of a finite set of system states, the state space of the system, all stochastic variables, and all decision variables must be represented in discrete form. For this reason, DP is ultimately limited in the size and complexity of problems it can handle. As problem size increases, DP's computational work grows exponentially to the point where even fairly simplistic systems can easily overwhelm computational resources. For a crude spatial model of bird population dynamics in a multi-stand forest, we met this computational wall immediately, estimating that DP would have to consider 10^{16} decision-state combinations per decision stage (Moore et al. 1999). In waterfowl harvest management, this wall may be fast approaching, especially as we hope to admit multiple mallard stocks and other species as new state variables, allow Flyway-specific regulations, permit more environmental predictors, and consider a larger set of competing models. These extensions may be accommodated by DP, but only if fine resolution of the state and decision space is sacrificed. Therefore, a DP approach may yield exact solutions to unrealistic problems.

A reasonable alternative, we feel, is an approach that sacrifices exact optimality for an ability to derive "good", approximate solutions to realistic problems. Our interest is in the genetic algorithm (GA) (Goldberg 1989), which belongs to a class of computationally-intensive procedures that rely on probabilistic rules, rather than exhaustive enumeration, to search for optima. In essence, the GA is a procedure that continuously resamples the entire space of all possible decisions through time or space, where information from the current sample provides guidance about where to next sample. The GA simulates an evolutionary genetics process in a population of computer organisms that most closely resemble the haploid, sexually-reproducing yeasts and green alga. One organism represents one "solution" to its environment, and the GA is a search for the optimal, or "best fit" individual in that environment.

To apply the GA to the mallard harvest problem, or to any other optimal control problem, we leave the backwards-time perspective of DP and instead consider collections, or *populations*, of possible decision paths forward through time. Each decision path prescribes a simulation to be performed by the GA, and each path generates an objective value to be analyzed by the GA. Starting from an initial population of harvest decision paths, each selected completely at random from the decision set, the GA evolves the population toward one which is superior to the first, both in mean and maximum value of the objective. Over the course of this evolution, the GA is "trained" to search in more promising areas of the decision space and to avoid others. In addition to the models of system dynamics, we need to specify (1) an initial system state, (2) a sufficiently long time horizon to observe stationarity, and (3) a representation of harvest decisions.

Decision paths are represented as *chromosomes* or *individuals* in the GA population. Chromosomes are comprised of *genes*, each of which represents a decision to be made at a point in time. Each gene takes on a decision value, or *allele*. If harvest decisions are in the range 0-50% in steps of 0.625%, then each gene (decision opportunity) has 81 possible alleles (decision choices). The model set, constraints, and initial system state define the *environment* in which the individuals "live." *Fitness* is the objective to be maximized; for example, cumulative harvest.

Three fundamental stochastic processes define the cycle of reproduction which carries the population through many iterations, or *generations*, of the GA. The first process is pairing, which is influenced by the relative fitness of individuals in the population. Each individual is selected at random for mating, but probability of selection is proportional to fitness. Thus, individuals of higher fitness are selected with greater probability than are individuals of lower fitness. Furthermore, individuals are selected "with replacement," so one individual may mate several times. Each mated pair produces one pair of offspring, and no parents survive to the next generation. Therefore, the population exactly replaces itself, and generations are non-overlapping. Through this process, highly-fit individuals are likely to contribute genetic material (sequences of decisions) to individuals in subsequent generations.

The second process is recombination. That is, paired individuals may exchange genetic material in the production of offspring. This probability is usually set very high ($\geq$0.60), so chances are small that offspring will be exact clones of the parents. If the outcome of a Bernoulli trial determines that the pair is to exchange genetic material, there are a variety of means to do so. The simplest is single crossover. One gene on the chromosome is chosen at random. Up to that gene, one child is an exact replicate of one of the parents, and the other child is a replicate of the other parent. Beyond the gene, the parental contributions to the children are switched. Recombination is a strategic gamble that genetic fragments contributing to high fitness in the parents are reconstituted in a new form that confers even greater fitness to one or both of the offspring.

The third process is mutation. After the offspring are formed through recombination, genes in each of the offspring are subject to a low ($\leq$0.20) but persistent rate of allele mutation. If a Bernoulli trial determines that a gene is to be mutated (i.e., that the harvest decision at a decision stage is to be changed), the current allele is replaced by another one randomly drawn from the allele (decision) set. The main benefit of mutation is to assure that the population maintains genetic diversity and does not converge on local optima.

Following mutation, the offspring are carried into the next generation to become the new mating pool, and the stochastic processes of pairing, recombination, and mutation are repeated. The GA typically evolves the population through many ($\geq$200) such generations. Despite the stochastic nature of each of these processes, the pattern of performance of the GA is fairly predictable for a given problem. Both the average population fitness value and the maximum fitness value usually increase from one generation to the next. At the last generation, the chromosome of the highest-fit individual is taken to be the approximate solution to the optimization problem, with the optimal value approximated by the fitness value. Because the procedure is stochastic, however, solutions are not necessarily identical among replicate GA runs. Therefore, the optimal solution is often taken as some average measure of solutions from several GA runs.

A straightforward implementation of the GA allows estimation of an optimal harvest policy for a particular model of harvest dynamics, a set of starting conditions (initial mallard population size and number of ponds), a given time horizon, and an array of possible harvest decisions. If the range of possible harvest rates (0-50%) is broken into 81 discrete levels, then the integers 0, 1, ..., 80 can be used as alleles to represent the harvest rate choices. Like DP, the decision variable in a GA must be discretized, but unlike DP, the discretization level can be made so fine that the entire decision set is practically continuous. If the time horizon is 15 years long, then the chromosomes are set up with 15 genes each. A GA population size is selected (e.g., 200), and the initial population is established by selecting a random allele for every gene in each chromosome. Each chromosome is "decoded" into a harvest decision sequence that is simulated through time under the given harvest dynamics model and the initial starting conditions. Fitness (15-year cumulative harvest) is then obtained for each chromosome. The pairing, recombination, and mutation processes then follow to create a new generation of chromosomes. These chromosomes are then decoded, evaluated, and propagated to the next generation, and this process repeats for a fixed number of generations (e.g., 200).

In practice, we have used an alternative approach that takes advantage of the Markovian nature of this system. In this approach, we "build up" a superior chromosome by incrementally lengthening the time horizon. The idea behind this approach is that the decision sequence in years 2, 3, ..., k+1 of an optimal decision sequence for a k+1 length time horizon likely resembles the optimal decision sequence found for a k-length time horizon, especially as k grows large. Therefore, as we search for an optimal decision strategy for a time horizon of length k+1, we may not want all chromosomes in the initial population to be drawn entirely at random. Instead, we may want to preserve the best decision sequence for a k-length time horizon in the genotype of one of the new k+1 length chromosomes; all the rest may be drawn at random. The potential advantage of such an approach over the straightforward approach is that a greater degree of solution quality and precision may be obtained for a given computational expense.

For each time horizon k, we plot the value of the first-year decision against k. We observe a pattern of large first-year harvest rates for small k, decreasing harvest rates as k increases, then stationarity in harvest rate as k continues to grow. These patterns are what we expect because when k is small, there are weak constraints to perpetuate the resource; however, when k is large, these constraints are much stronger. If the decision sequences we obtain are truly optimal, then the first-year decision values of these sequences should agree with decision values obtained from each stage iteration of DP. In this sense, the "build-up" procedure provides a product similar to that provided by DP, but the means by which these two algorithms pursue these products are entirely different. The first-year decision plots from the two procedures may be overlaid to assess performance of the GA. Agreement between the two procedures can be made arbitrarily close by careful selection of GA parameters (e.g., rates of recombination and mutation, population size, number of generations).

For deterministic versions of both additive and compensatory mallard harvest models (assuming weak density-dependent recruitment) described in Johnson et al. (1997), first-year harvest decisions provided by the GA closely agree with those provided by DP over a wide range of initial duck and pond states. Furthermore, GA solutions are fairly precise: harvest rates from replicate runs of the procedure cluster tightly around a mean value.

The GA can find good decision policies when the system is stochastic. For example, we may wish to incorporate random effects of rainfall on future pond states or random harvest outcomes given a harvest decision. In the deterministic case, a single sequence of harvest decisions provides a single value of cumulative harvest every time that particular sequence is simulated. In the stochastic case, one simulation of a single harvest decision sequence provides a realization of a random harvest outcome: several simulations of the decision sequence provide a distribution of cumulative harvest. Under stochasticity, the GA performs not one but several simulations of a single chromosome to obtain an expected measure of fitness. Therefore, identical chromosomes may provide different measures of fitness and thus receive different probabilities of pairing. As a result, the optimization surface (cumulative harvest response plotted against decision values) is noisier and less well-defined than in the deterministic case.

First-year harvest decisions under stochastic versions of the mallard models have wider variance than before. For the compensatory model, DP solutions are usually covered by a 95% confidence interval around the mean GA solution. This is not the case, however, for the additive model, for which the GA tends to overestimate the optimal harvest rate at low mallard population sizes and underestimate optimal harvest rate at high mallard population sizes. We are currently working to understand why the GA behaves in this way for the additive model but not for the compensatory model.

We are also beginning to address how the GA can be used to derive adaptive optimal harvest decisions. We now expand the state space to include probabilities for each competing model, and we alter the GA to simulate effects of harvest decisions on probability states as well as on physical states. The greatest challenge will be the generation of likelihood functions under each alternative model, a task that will need to be done at each gene on each chromosome. Once the likelihoods are obtained, the GA will use Bayes rule to project the model probability states through time (down the chromosome).

In a first test of this revised algorithm, we obtained encouraging results. Assuming that harvest mortality is compensatory but assuming uncertainty about the form of recruitment, the GA solution agreed with the solution provided by DP (program ASDP; B. C. Lubow, Colorado Cooperative Fish and Wildlife Research Unit). This was not the case when we assumed additive harvest mortality and uncertainty about recruitment, or when we assumed uncertainty about both harvest mortality and recruitment. Because either case involves policy estimation under the additive model, we were not surprised by the outcome. We expect to see greater agreement after we resolve concerns about application of the GA to the additive model.

The GA provides some distinct advantages over DP and may be a viable alternative to DP in some problems of optimal control. The GA can accommodate multi-state models that are large, complex, and stochastic. System models need not be Markovian. State variables and stochastic variables may be discrete or continuous. Decision variables must be discrete, but they may take on many values. The GA is somewhat easier to conceptualize than the DP algorithm because the GA considers decisions simulated forward through time. Despite its probabilistic sampling basis, the GA provides "good" solutions to a variety of complex problems.

Unlike DP, however, the GA is unable to provide solutions that are guaranteed to be optimal. The GA also does not automatically provide solutions over the entire state space like DP does. Therefore, under the GA, it is difficult to study the pattern of decisions over the state space or to simulate a state-specific policy through time.

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Communications Update - *Dave Case and the Communications Team*

Dave Case gave a brief overview of communications efforts since the last working group meeting. Although communications remained a priority for AHM implementation, communications efforts in the past year have been primarily "maintenance." Less time and money was spent on communications in 1998 than in 1997 and considerably less than in 1995 and 1996. No systematic efforts were made in 1998 to address long-term communications issues outside the normal efforts. A considerable proportion of communications time was spent on framework extension issues, primarily with internal audiences.

Dave Sharp pointed out that there is still a considerable need for internal communications to build the understanding and support needed among technical and administrative audiences. He feels we are still behind in this respect. Dave Case pointed out that the role of communications is to facilitate implementation to AHM and to help deal with difficult issues such as framework extensions. He commented that such issues are part of the management process and we should view them as things to work on and resolve, knowing that other issues will take their place once that issues passes or is resolved. In other words, we need to "embrace conflict" as part of the AHM process instead of viewing these perturbations as anomalies.

Dave Case then gave an overview of the communications strategy. The working group agreed the issues identified at the 1998 meeting combined with the issues identified through the course of this meeting including the break-out sessions provide a good foundation on which to update the communications strategy. Dave discussed the time and funding limitations that exist within MBMO for development and implementation of communications efforts. It was emphasized that communications is critical, and that it is everyone's responsibility. As a next step, Dave Case will update the strategy and distribute it to for review. Once the plan is completed it will be distributed to the full group for implementation.

Communications Workshop - *Fred Johnson and Working Group*

While our recent communication efforts have been successful, they also have become more defensive or reactionary. We simply haven't had the time or resources to plan and act more strategically. The AHM Working Group has been aware of this problem for some time and has continued to urge a more pro-active approach. As recently as last April, the AHM Working Group asked the Service to commit resources to enhance communication about a broad suite of harvest-management issues. I believe our ability to meet these communication needs will determine in large measure the long-term viability of AHM (or of any other coherent approach to harvest management).

Our long-term communication needs are more complex, broader in scope, and more institutional in nature than those of the last four years. Because of the explicit and formal nature of the AHM process, managers are being forced to confront long-held beliefs about their ability to understand and influence the managed system, and about the potential of biological science to engender policy consensus.

There postulates were presented to the group for discussion:

(1) *goal setting* - Effective management planning and evaluation depends on agreement among stakeholders about how to value harvest benefits, and how those benefits should be shared. It is these unresolved value judgements, and the lack of effective structures for organizing debate, that present the greatest threat to AHM.

(2) *limits to system control* - Much of the traditional perception of fine management control (i.e., ability to reliably predict and control harvests) appears to be delusional and, thus, there are unrecognized limits to short-term yields and the learning needed to increase long-term performance.

(3) *management scale* - The history of waterfowl management has been characterized by persistent efforts to account for increasingly more spatial, temporal, and organizational variability in waterfowl biology. The cost-effectiveness of this approach is questionable; moreover, limited resources for monitoring and assessment rarely permit selection of the scale with the highest net benefit.

It may be these institutional issues, more than any of the most daunting technical problems, that pose the greatest challenge to the long-term success of AHM. Coping with these issues will require innovative mechanisms for producing effective dialogue, and for handling disputes within a process that all parties regard as workable.

The Working Group was divided into three breakout groups; each was assigned one of the postulates, and directed to address the following questions:

(1) Is this a legitimate concern? Is there empirical evidence for or against?
(2) What are the implications for AHM?
(3) What are the technical / institutional needs and constraints in dealing with this issue?

(4) What are the communication problems and needs?

In response to these questions, the following material was presented to the Working Group by each of the breakout groups.

Postulate #1.--Concerns about harvest distribution continue to be a (**the**) basic issue for waterfowl harvest managers. The objective developed for AHM is a reasonable reflection of the overall and long-term mallard harvest objective. However, the AHM objective does not capture the historic and current concerns about "who" has an opportunity to or actually does harvest ducks. Thus, annual changes in regulations have been typical of AHM to date.

Results from limited survey data for hunters (e.g., Ringelman 1997 and some state-specific efforts) and among waterfowl managers (e.g., fall 1996 survey of Flyway Councils) do not necessarily correspond (season lengths, maximum bag limit, hen mallard bag limits, etc.). And the issues that affect harvest management decisions (current example - frameworks extensions) are not necessarily concerns of the majority of hunters / managers / administrators.

Joint recommendations #4 and #5 from the Joint Flyway meeting in 1996 (Kansas City) provide one step in identifying a schedule and structure for harvest management. To what degree should this be expanded / amended? What is the forum within which this should be discussed and agreements reached? If 90% agree, will this ensure that AHM will proceed?

Some questions and hypotheses included:

(1) Agreement among stakeholders is possible. Value judgements can be resolved in a structured debate
(2) What is meant by value of harvest, how is this measured?
(3) Allocation / sharing of the harvest is the basic issue (i.e., maximum harvest can be distributed in an infinite number of ways among/within flyways)
(4) What is the likely forum for debate? (Who should be responsible? Who does the work?)
(5) Is the value of harvest the same for the AHM process (technically - as reflected in the objective function) and overall, for harvest management (the perception and/or reality of harvest, hunting success, hunting opportunity, etc.)?

Questions exist about the degree to which knowledge about what the majority of hunters prefer would affect ability to amend harvest management regimes. Reasons for some skepticism include:

- Generally we believe that most hunters are "satisfied." Yet a minority can have a legitimate (passionate, vocal, influential, etc.) concern that is not accommodated by a particular set of regulations. The "minority" is not necessarily the same group of hunters among years.

- We currently manage for the minority of hunters who are shooting the majority of ducks.

- How does hunting success relate to hunter satisfaction? A number of surveys indicate that other factors (e.g., seeing waterfowl, hunting with family, etc.) are more important than harvest in affecting hunter satisfaction.

- Perception and expectation may not match reality (i.e., "It's going to be a really large fall flight ... good hunting season" - "I had a really poor season."). We actually determine and end up managing hunter perceptions.

- There is considerable difference in preference, satisfaction, success, perception, and experience even in local areas. To what degree does majority satisfaction reflect the likelihood that certain harvest management issues will "go away?"

- The perception of "fair" may be more important than actual measures of harvest or hunter satisfaction (however indexed).

The conclusion: Explicit consideration of hunter satisfaction would provide information and justification / rationale for harvest management decisions; however, it would not necessarily resolve contentiousness and regulations "end runs."

Not resolving the debate about harvest distribution likely will lead to "business as usual." As long as this does not result in a return to "business as in the past," (annual debate and decision in July about any number of different regulations) the AHM can continue to provide a structure for recommending harvest management decisions and learning about harvest and habitat impacts. The degree to which AHM provides new insights already has been affected by factors such as a lack of measured harvest rates, lack of a stable set of regulations options etc., and gains under AHM will depend on how these and other issues are resolved.

Historic patterns of harvest distribution among (within) flyways has evolved into an "uneasy" balance that was achieved after 50+ years. There is no current effort to review the basis for "allocation" or changes in the distribution of harvest. The forum already exists (flyways, National Flyway Council, IAFWA, etc.) to forward this dialogue; however, it has not occurred. There is not likely the time available among administrative representatives to accomplish a comprehensive review of harvest distribution / allocation. Should there be a goal related to hunter satisfaction or harvest distribution ("dividing the spoils")? If so, outside assistance probably would be necessary because few involved in resource management have the experience or training necessary to develop goals involving value judgements.

There is no "common currency" to describe harvest management desires / regulations at different scales. The AHM objective of maximum harvest is a product of hunter numbers, hunter success, and hunting opportunity. However, the preferred regulation element (bag limit, season length, season timing, etc.) varies among regions. In addition, there is an inequitable distribution of ducks, hunters, and habitat as well as annual differences in weather, duck numbers, migration timing, etc.

There is not a complete understanding among managers / administrators of the consequences of some regulations proposals (with regard to impacts on distribution of harvest as well as impacts on AHM objectives). Assumptions and perceptions of hunter preferences largely have not been based on survey data nor monitored to determine if changes have occurred. Expectations among hunters likely are affected / "created" by agency and media reports; these are not necessarily confirmed by local or individual hunting experience. To what degree would education about success rates, harvest levels, hunting opportunity, etc. change views about regulations changes?

There is limited documentation of efforts to review harvest allocation. This is not consistent with the explicit nature of AHM. The technical process (via AHM) has progressed beyond a corresponding effort to reach agreement about harvest distribution. Waterfowl harvest management involves two primary components that are integral to success: (1) establishment of goals and objectives and (2) determining the consequences of management actions. Although the latter has been explicitly incorporated into the AHM process, several elements of harvest management goals have not been clearly defined.

Recommendation: Incorporate measures of hunter preference and satisfaction into waterfowl survey efforts (e.g, HIP). Explicit inclusion of hunter satisfaction would provide information and justification / rationale for harvest management decisions that currently are not available. Ringelman (1997) provided a baseline for comparison and initial standards for hunter expectations for harvest management. A systematic process for informing future management decisions is needed. Elements needed include:

- identify information needed from a survey (objectives)
- determine the feasibility / legal and other constraints
- establishment of a task force to develop the survey
- develop a plan for reporting results and incorporation into harvest management decisions.

Lack of agreement on the value of harvest jeopardizes progress made under AHM. The lack of a structured and documented review / debate about harvest management objectives poses a threat to AHM or any explicit, structured process of regulations development. A forum for review and documentation of the history and status of harvest management is needed to ensure that the philosophical underpinning for harvest management is as explicit and rigorous as the technical process provided by AHM.

Recommendation: Develop a forum for review of the history of duck harvest regulations, trends in harvest distribution, hunter preferences and the relationship between the regulations process and harvest management decisions. Important aspects include:

- objective of a harvest management forum

- committee composition (e.g. federal, flyway, administrative, technical)
- deadline for reporting
- forum for reporting (e.g. Joint Flyway Council in July 2000)
- forum for resolution (initiated at Joint flyway meeting)

Postulate #2.--There was considerable discussion about how to interpret this postulate. It was reworded as: "The degree to which harvest regulations affect harvest rates is much less precise than is commonly believed." Key components are partial control of harvest and partial observability of the system (e.g., measurement of harvest rates, population size).

Is this a legitimate concern? Is there empirical evidence to support the postulate?

Clearly, we can control harvest and harvest rates to some extent through regulations. The degree to which a given change in regulations produces reliable and measurable changes in harvest depends on the situation (e.g., change of 1bird in the bag limit produces large effects for canvasbacks; small changes for male mallards). In waterfowl management there is a long history of fostering the idea of very fine management control, and an impressive variety of small regulatory changes have been made through time. However, partial control results in large variation in harvest and harvest rates associated with a given set of packages (e.g., large variations in harvest over time with no changes in regulations). Likewise, partial observability decreases the precision of our measures of metrics of interest (e.g., current problems with estimating harvest rates). Given partial control and partial observability, we often cannot observe changes in harvests and harvest rates unless relatively large changes in regulations are made.

What are the implications for AHM?

Because AHM sets explicit objectives and is data-driven, partial control and partial observability place important constraints on our ability to deal with changes in regulations. We need to have enough difference in regulation packages to measure changes and to help us learn something about the implications of regulations change.

Partial control adds to the uncertainty associated with the outcomes of different sets of regulations, and there is limited ability to evaluate many regulation issues that are important to waterfowl managers. The frameworks issue as a example: is it really possible to reliably change bag limits/season lengths to reliably "offset" framework extensions? Even if we can, how precise is our ability to measure whether offsets have truly occurred?

AHM methodology explicitly recognizes that there is greater uncertainty (imprecision and potential bias) associated with regulations that are outside the realm of experience. Consequently, regulation changes that appear minor may have dramatic impacts on optimization outcomes.

As we improve precision by increasing management control and/or ability to measure responses, we should be able to evaluste the effects of finer levels of regulatory change. So, for example, determining band reporting rates will be a major benefit.

What are the technical/institutional needs and constraints in dealing with this issue?

The priority for (state) administrators is generally to satisfy the immediate needs of duck hunters. This goal is often approached through attempts to provide additional opportunity via regulation changes; effects on harvest or harvest rates may be secondary. In addition, there is personnel turnover and short-term goals often are favored over long-term goals.

An important constraint is continued and improved "buy-in" from all participants in AHM; this includes many levels (hunters, technicians, agency administrators, politicians). It may be unrealistic to expect a high degree of stability in regulations. Given historical perceptions and agency goals/priorities that differ from explicit objective function of AHM, some level of "tinkering" with regulations may continue to be desired. If the "penalty" for these "small" changes is too high (e.g., more time spent in conservative packages), support for AHM may erode.

Expectations for fine control through regulations places increased demands on technicians. The problem is not the AHM process, it is our ability to monitor and control what we can do. You may not like the results - but it is not the process - it is the entire system - our ability to control and measure.

A major technical need is to better understand hunter behavior. Are there other ways to control harvest rates produced by hunters than current tools (bag limits, season length, frameworks), and how do these various tools interact to influence hunter behavior?

Resources are limited to improve capabilities to observe the system.

What are the communication problems and needs?

Instability and complexity of regulations are deadly to AHM - this process must work against historical perceptions that changes in regulations can be easily accomodated.

An immediate communication need is that we have lost the tools to get this work done (i.e., harvest rates), and that we have limited resources. In the short term we are going to have to deal with a lot of uncertainty. The more time we spend on analysis of small changes , the less we spend on learning the whole system and looking at new approaches (additional cost).

An important element of AHM is to learn. Increased knowledge will increase our ability to manage the system effeciently; must sacrifice some desires for changes now to increase rate of learning.

Internal and external audiences need to understand the objectives and constraints and support the AHM process. Much of this message is in contrast to our telling people that we can micromanage ducks for the past 50 years.

Differences among the current AHM packages (a compromise among the flyways and USFWS) imply that this is the level at which we can predict and measure changes in harvest rates. It is unclear what other changes (at finer scales and outside the realm of experience) can be accomodated in AHM. It would be valuable to provide a way to better assess, given partial control and partial observability, how likely it is a given proposed change in regulations will produce a measurable effect. One possible message (mainly to administrators?): "Understanding the effects of differences in regulations at the level of the current packages is stretching our technical ability to the maximum; understanding (predicting) effects of smaller (and more complex) changes may be beyond our technical capabilities." Note this could be interpreted to conclude that if the effect of a change is small enough that it can't be measured, why not do it.

Administrators and hunters must understand the relationship betweem AHM process for mid-continent mallards and regulations for other stocks/species. An early perception of AHM was that regulations would be more simplified, but that hasn't happened. There is a need to provide updates on where we are with AHM in relation to overall duck regulations.

Postulate 3.--The cost effectiveness of accounting for more spatial, bio-organizational and temporal variability is questionable and resources for monitoring and assessment may be too limited to address this variability at a scale fine enough to reap the highest net benefits.

The group discussion generated several basic conclusions:

(1) There are several motivations to address smaller units of duck resources, including: perceived harvest opportunity, equitability, responsible management at a "population" level, and preserving options in the future.

(2) Harvest management can occur at a scale smaller than continentally or by flyway, but costs, feasibility of integrating small scale decisions, and understanding the effect of this integration, will limit the degree of management scale.

(3) There is a need to recognize smaller scales (e.g. well-defined populations or species of concern) to avoid management at too gross a level to consider the effect on other stocks. Criteria should be developed to identify which stocks should be managed at a smaller scale or incorporated into the AHM process, and these criteria should include more than population status and data gathering ability.

(4) That there are at least three approaches to decision making: (a) decision-making without acknowledging uncertainty; (b) decision-making that acknowledges uncertainty but does not adapt; and (c) decision-making that acknowledges uncertainty and adapts.

In response to the specific charges, we found that:

(1) This is a legitimate and recognized concern amongst technicians, but it is less clear that administrators and the public understand this.
(2) The AHM process needs to develop a "sub-process" for identifying management scale, or which stocks to work toward integrating into the AHM process.
(3) It was unclear to the group whether there are technical constraints, but there are clearly institutional/financial constraints.

Two specific communications needs were identified:

(1) Management scale is limited, and the formal AHM process will not likely solve all individual harvest concerns.
(2) This limit to management scale needs to be formalized, the process for refinements to management scale needs to be developed and communicated.

Current Conditions and Outlook for Breeding Waterfowl - *Jim Dubovsky*

Temperatures during winter 1998-99 throughout the northcentral U.S. and the prairie provinces of Canada generally were higher than average. In the northcentral U.S., the Great Lakes States, and southern prairie Canada, precipitation was above average. However, amounts were much below average in northern portions of the prairie provinces. As a result, the Palmer Drought Indices (an indication as to how "wet" the prairies may be) depict average to above-average moisture levels in the northcentral U.S. and southeastern Manitoba and Saskatchewan, but dry conditions in southern Alberta and northern portions of the prairie provinces. Most of the snow in the prairies had already melted by the first of April, suggesting little potential for additional runoff to fill basins this spring. Using the size of the mallard breeding population (10.6 million) and the number of ponds in Prairie Canada (2.5 million) last spring, along with the harvest rate of adult male mallards predicted for the "liberal" regulatory alternative used during the 1998-99 hunting season (13.3%), we predict that the 1999 spring population of midcontinent mallards will consist of about 8.8 million birds, and that the number of ponds in May in Prairie Canada will be approximately 3.0 million. *If* (1) these population sizes for mallards and ponds are observed in May, (2) model weights for the 4 models used in the AHM process do not change substantially, and (3) the same regulatory alternatives that were used during the 1998-99 season are used for the 1999-2000 season, then the optimal regulatory choice for this fall would be the "liberal" alternative.

Updating Posterior Probabilities - *Bill Kendall*

An important element in AHM is the learning process. Under the conceptual framework we are using this learning process is expressed through changes in relative confidence (i.e., weights) in each of the four models in our model set. A sensible way to accomplish this updating process is to compare the predictions of each model with what is in fact observed from the May Survey. If each model were completely deterministic (i.e., predicted just one number), and if the May Survey produced the exact number of ducks in the population (i.e., no partial observability), we could come up with more than one reasonable ad hoc approach to updating model weights. However, due to uncertainty in the BPOP, the number of ponds, and the realized harvest rates under each regulations package, each model predicts a distribution of values around the one arrived at by plugging numbers into the prediction equation. In addition, the BPOP estimate that we compare with the predictions also has uncertainty (i.e., variance). This makes the updating process more complex, becoming a process for comparing distributions instead of individual estimates. Bayes's Theorem provides a tool for updating that is both logical and statistically rigorous.

Since beginning the AHM process we have gone through the updating process three times. In 1996 and 1998 the observed BPOP was very close to the mean of the prediction intervals for the two models that assume additive mortality, and far out in the tails of the predictions from the models assuming compensation. The 1997 the results were in the opposite direction, but not quite as extreme. Therefore at this point there is very little weight on the two models assuming compensation. The relative confidence in weakly and strongly density dependent recruitment has changed somewhat also, with strong density dependence being favored most.

Several questions arise in assessing this updating process, especially given the rapid change in the weights initially. First, the evidence heavily favored the additive mortality model in the first and third years and favored the compensatory mortality model in the second year. Would the resulting weights in the third year have been different if the order of these results had been changed (e.g., the compensatory mortality model favored in the first year, and the additive mortality model favored in the second and third)? No, the weights after three years are independent of the order in which the results occurred.

Second, the updating process in 1996 was based on estimated realized harvest rates, whereas in 1997 and 1998 it was based on projected harvest rates, which entailed poorer precision. Would the results of the updating process have been much different if the projected harvest rates had been used in 1996 as well? No, the results would have been very similar to what we have now.

Third, how much does the uncertainty in harvest rate affect the results? A simple scenario analysis based on a one-year result like 1998, assuming equal prior weights, indicated that at the current 25% coefficient of variation (cv) in harvest rates almost no weight would be on the compensatory mortality model, at 50% cv about 1% of the weight would be on compensation, and at 100% cv about 23% of the weight would be on the compensatory mortality model.

Future investigations in this area include reflecting the uncertainty in parameter estimates in the updating process and reviewing whether the propagation of model predictions over time could be refined.

Modeling Survival of Midcontinent Mallards - *Bill Kendall*

The current model set in AHM currently includes harvest mortality of mid-continent mallards as either completely additive or completely compensated for up to a threshold. These are reasonable models for the time being, but not completely satisfactory for two reasons. First, estimated extent of compensation varied from almost completely compensatory (in the 1970's) to almost completely additive (in the 1980's) based on published analyses (Burnham et al. 1984, Smith and Reynolds 1991). Our preliminary analyses allowing the extent of compensation to vary over time found the same thing in two out of three banding reference areas.

Second, and relatedly, the current models for mortality do not include any mechanism for compensation. For example, a model that includes density dependence would predict each of the results above, depending on the density at the time. The key is to find the mechanism that drives the process. We are in the process of investigating this, and facing two problems. First, because of the large geographic scale of the distribution of mid-continent mallards in both the breeding and wintering times of year, it is difficult to identify and assess at the appropriate scale the factors that drive mortality. Second, recent findings by Nichols et al. (1995) indicate that reporting rate of harvested mallards varies geographically and in some places by sex. This variation and the overall uncertainty in reporting rate (and hence kill rate) present complex computer programming and numerical problems that need to be resolved to more properly model survival. This work is ongoing.

Modeling Reproduction of Midcontinent Mallards - *Jim Dubovsky*

Results of site- and time-specific research projects conducted in Prairie Canada and the northcentral U.S. suggest that mallard recruitment may vary spatially and in response to changes in upland habitat conditions. Yet, the ability to detect similar patterns at large scales (i.e., with fall age ratios of the midcontinent population of mallards) has been problematic. Part of the difficulty probably is due to the coarse-grained nature of the information resulting from operational monitoring programs (i.e., region-specific fall age ratios cannot be calculated). To investigate further whether there is evidence that recruitment varies spatially, I calculated for each survey stratum of the July Production and Habitat Survey an index to recruitment rate (i.e., [Class II + Class III broods]/number of mallards in spring). The results were consistent with evidence that recruitment rates vary spatially as well as temporally. Therefore, I sought a way to incorporate a spatial dimension into models predicting mallard fall age ratios. Building on the idea that mallards tend to settle in areas with abundant water in spring, and the evidence which suggests that recruitment varies spatially, I hypothesized that the distribution of ponds in Prairie Canada and the northcentral U.S. in spring influences subsequent mallard recruitment. Therefore, I calculated the geographic "center" of the distribution of ponds in the Prairie Pothole region (i.e., strata 26-49) for each of the years from 1974-95. Furthermore, I included a habitat variable, the annual slope between crop acreage and May ponds across survey strata, in an attempt to increase explanatory power of the model. The idea behind the latter variable is that, as the slope of the relationship increases positively, ponds and crop acreage become more coincident on the landscape. Because mallards produce few young in areas predominated by agriculture, the close association of ponds and crops should result in relatively low fall age ratios. Conversely, as the slope between these variables decreases or becomes negative, grassland acreage (i.e., the compliment of crop acreage) should be better juxtaposed with ponds, positively impacting recruitment. To test these hypotheses, I calculated all possible regressions to identify relationships between the annual fall age ratio of female mallards and the following independent variables: (1) the size of the midcontinent mallard population in spring, (2) the number of ponds in May in strata 26-49, (3) the latitude of the center of the pond distribution, (4) the longitude of the center of the pond distribution, (5) the slopes of annual relationships between crop acreage and pond abundance, and (6) selected interactions of the aforementioned independent variables. The "best" model ($R^2 = 0.81$, $P < 0.01$) included negative associations with (1) and (3), and a positive relationship with (2), consistent with my a priori hypotheses. The "best" 6 models, as indicated by values for Akaike's Information Criterion, all included a spatial component (i.e., either latitude, longitude, or their interaction); only one included the slope variable. These results suggest that landscape attributes other than just numbers of ponds might be useful for predicting the fall age ratio of the midcontinent female mallard population, although the appropriate landscape features and the mechanism(s) by which those features influence the age ratio have not been identified. The problem managers continue to face when building recruitment models is how to aggregate small-scale features to predict large-scale effects. Future work by the newly formed Adaptive Management and Assessment Team will focus on methodologies that may enable managers to monitor recruitment at relatively small scales, to better predict regional pond abundance, and to collect refined information about upland and wetland habitats across broad scales. Such information should improve our ability to model the population dynamics of mallards.

Assessing the Effect of Habitat on Midcontinent Mallards - *Rex Johnson*

Of particular importance to conserving North American waterfowl is understanding how habitats affect changes in the status of waterfowl populations. The ability to predict changes in population size due to annual habitat condition would enable harvest managers to make more accurate population projections, set better regulations, and learn more about the impact of those regulations on population abundance. The Adaptive Management and Assessment Team (AMAT) was established to clarify the linkages between the temporal and spatial dynamics of migratory bird abundance, harvest and habitat condition. As the first steps in fulfilling this mission, AMAT is developing a suite of projects with a unified focus — evaluating the effects of temporal and spatial dynamics of habitat on midcontinent mallards throughout their annual range. Projects in the Prairie Pothole Region (PPR) and Mississippi Alluvial Valley (MAV) have been initiated. The goal of these projects is to inform the AHM process about midcontinent mallard population changes attributable to habitat, in ways that lead to refined habitat objectives and site-selection criteria for habitat management prescriptions.

Predicting waterfowl settling patterns and production in the Prairie Pothole Region of North America: effects of temporal and spatial habitat variability.-- AMAT is engaged in a multi-stage investigation designed to improve predictions of local and regional-scale waterfowl production from the PPR. The project has three primary objectives:

(1) develop models which predict local and regional-scale duck settling patterns and production from habitat characteristics;
(2) develop cost-effective protocols for monitoring habitat condition in the PPR; and

(3) recommend refinements to current duck production monitoring programs.

AMAT is pursuing these objectives in three stages. Stage 1 includes a retrospective analysis of historic habitat and waterfowl population data. From these data we will develop predictive models of waterfowl settling patterns and production, and compare variability in population and habitat parameters at a variety of spatial scales. In stage 2, habitat characteristics will be measured with greater resolution from digital aerial imagery, and over a period of years, the production models developed using historic data will be refined. AMAT also will provide an assessment of the USFWS's primary mechanism for monitoring annual waterfowl production, the Waterfowl Production and Habitat Survey. If data from that survey are inadequate to support modeling efforts, modifications to survey methods will be recommended to the USFWS. In stage 3 of the project, AMAT will explore sampling strategies, data sources, and analytical methods to improve the timeliness and cost-effectiveness of PPR habitat monitoring programs. AMAT will focus initially on assessing the affects of landscape condition on duck settling and production reflected in historic data acquired during May and July breeding ground surveys, and on developing habitat monitoring protocols using multi-phase sampling. Multi-phase designs integrate satellite and aerial imagery of varying spatial and spectral resolutions in order to assess habitat condition for large areas.

Hydrological modeling in the Lower Mississippi Alluvial Valley.--Despite the importance of natural flooding in the MAV in providing habitat for midcontinent mallards, the spatial and temporal dynamics of natural flooding, and their impacts on mallard populations, remain poorly understood. AMAT is cooperating with scientists at NASA's Goddard Space Flight Center to classify the distribution of flood waters at know stream-gauge elevations. By classifying spatially coincident satellite images acquired under different hydrologic conditions, it is possible to develop a spatially explicit model predicting the distribution of flooding from historic data sets or in real time from existing stream-gauge monitoring programs, and to develop seasonal indices of habitat distribution and condition that can be related to changes in mallard population status.

Managing the Harvests of Eastern Mallards - *Fred Johnson*

Recent assessment activities have focused on two issues: (1) the current model of recruitment; and (2) the mechanics of extending the current AHM protocol to consider the annual status of eastern mallards.

Recruitment model.--I first refit the current recruitment model using a logistic transformation of fall age ratios:

$$\ln\frac{\acute{A}_t}{1-\acute{A}_t} = a-b(BBS_t)+c(PPT_t)$$

where

$$\acute{A}_t = \frac{A_t}{A_{\max}}$$

and

$$A_t = A_{\max} \frac{e^{a-b(BBS_t)+c(PPT_t)}}{1+e^{a-b(BBS_t)+c(PPT_t)}}$$

and where A_t = fall age ratio of females in year t, A_{max} = maximum age ratio, BBS = weighted Breeding Bird Survey index for the northeastern states, and PPT = cumulative precipitation in northeastern states during March to May. This curvilinear model fits the data nearly as well as the existing linear model, and it has the advantage of placing realistic limits on recruitment at extreme population sizes.

This improvement does not overcome, however, two major sources of uncertainty in the recruitment model for eastern mallards. The first concerns the strong negative relationship between population size (as indexed by the BBS) and fall age ratios. It is unclear whether this relationship truly represents a density-dependent response in reproduction, or merely a statistical association with no underlying biological mechanism. To investigate the implications of the uncertainty about density dependence, I constructed an alternative recruitment model by using the upper 95% confidence limit of the regression coefficient for population size. This alternative model, which depicts only weak density dependence in recruitment, was associated with a much more conservative harvest strategy than the strongly density-dependent recruitment model.

The second key uncertainty involves the relationship between population size as estimated from the fixed-wing and plot surveys (N), and population size as indexed from the BBS. In constructing the recruitment model, it was necessary to rely on the BBS index because it was available for a relatively large number of years. However, managers wish to use population size from the fixed-wing and plot surveys as the criterion for harvest decisions, meaning that the relationship between N and the BBS index must be known. Unfortunately, there are only seven years in which both population measures are available, resulting in considerable uncertainty about the relationship between the two. Until more years of data are available, I suggest a model relating N and the BBS index that lacks an intercept term because it generates a risk-aversive harvest strategy.

Extending the AHM protocol to account for eastern mallards.--I first examined the potential for regulatory prescriptions to differ between midcontinent and eastern mallards. I generated independent optimal strategies for midcontinent and eastern mallards, assuming that all Flyways would use the same regulatory option. Upon simulating these two strategies, I found that the midcontinent stock would be managed primarily by the moderate (22% of years) and liberal (64% of years) options. The eastern stock would be managed almost entirely with the liberal option (98% of years). If we assume that the two stocks are independent (no exchange, no correlation in relevant environmental conditions), we can estimate the percentage of years in which there would be conflicting regulatory prescriptions for the two stocks:

	Eastern			
Midcontinent	**VR**	**R**	**M**	**L**
VR	0.0	0.0	0.0	2.1
R	0.0	0.1	0.2	12.2
M	0.0	0.2	0.3	21.0
L	0.0	0.5	1.0	62.4

The down diagonal represent the percentage of years in which there would be no conflict in regulatory options (about 63%). Above the diagonal represents years in which the eastern stock would be harvested too lightly if all Flyways were driven by a midcontinent strategy (about 35%). Below the diagonal represents years when eastern mallards would be harvested too heavily (2%).

Extension of the current AHM protocol to account for the annual status of eastern mallards involves:

(1) augmentation of the decision criteria to include population and environmental variables relevant to eastern mallards;
(2) revision of the objective function to account for harvest management objectives for eastern mallards; and
(3) modification of the decision rules to allow Flyway-specific regulatory choices.

To understand the management implications of these decision-making elements, I developed an optimization procedure that permits eastern mallards to be integrated into the current AHM protocol to varying degrees. I then examined three harvest strategies:

(1) a coarse-scale strategy, corresponding to the current AHM protocol for midcontinent mallards;
(2) a mid-scale strategy that accounts explicitly for the annual status of eastern mallards, but forces the same regulatory decision in all Flyways; and
(3) a fine-scale strategy that accounts explicitly for the annual status of eastern mallards, and also allows Flyway-specific regulatory choices.

Using an objective function that maximizes long-term cumulative harvest (subject to the constraint of the NAWMP goal for midcontinent mallards), I simulated these three strategies and derived the performance metrics in the following table. Metrics are annual means, with standard deviations are in parentheses. I assumed perfect control over harvest rates in these simulations.

	Harvest rate				Population size (millions)	
Management scale	Central & Pacific	Mississippi	Atlantic	Harvest utility (millions)	Midcontinent	Eastern
coarse	0.095 (0.027)	0.095 (0.027)	0.095 (0.027)	0.798 (0.353)	6.90 (0.57)	1.31 (0.14)
mid	0.102 (0.024)	0.102 (0.024)	0.102 (0.024)	0.802 (0.326)	6.64 (0.54)	1.28 (0.12)
fine	0.129 (0.064)	0.065 (0.032)	0.285 (0.064)	0.888 (0.320)	7.17 (0.54)	0.75 (0.25)

These simulations suggest that the expected gain in management performance (i.e., harvest utility) from full integration of eastern mallards may be less than 15%. The gain in management performance would be less when using regulations with limited control over harvest rates. The average population size of eastern mallards appeared to be sensitive to management scale, but midcontinent population size was not. Further work is needed to understand the implications of various objective functions, and of regulations that allow only limited control over harvests.

Modeling Western Mallards - *Sue Sheaffer*

The breeding range of western mallards includes the Pacific Flyway states (including Alaska), the Yukon Territories, and British Columbia. Although mallards breeding in southern Alberta are harvested primarily in the Pacific Flyway, estimated survival and reproductive parameters for these birds are similar to those for birds breeding in southern Saskatchewan. As a result, mallards breeding in southern Alberta are modeled as part of the mid-continent population. Breeding pair surveys in the lower Pacific Flyway states were initiated in 1990 and have suggested a relatively stable or slightly increasing population size in this region during 1990-98. Highest numbers of breeding birds occur in California, Oregon, and Washington. Presently there are no breeding pair surveys and limited banding data for mallards breeding in Alaska or British Columbia. Managers will be unable to model the population dynamics of birds breeding in Alaska or British Columbia until operational surveys and banding programs are established in these regions. The initial working model for western mallards will focus on identifying key uncertainties affecting recruitment and survival of mallards breeding in the coastal states of California, Oregon, and Washington, where there is sufficient banding, harvest, and population survey data. Annual survival and harvest rates for these birds are estimated using band-recovery data from California, Oregon, and Washington. Estimated natural mortality rates are similar to those for mid-continent mallards. Models of survival for western mallards will represent the uncertainty about whether harvest is an additive or compensatory form of mortality. Annual reproductive rates are estimated using female age ratios in the California harvest during October when the harvest is comprised primarily of stocks from the lower Pacific Flyway states. Historical band-recovery data suggest that female mallards breeding in southern Alberta are not present in the California harvest during October. Efforts are ongoing to identify environmental and demographic factors that characterize the reproductive process for western mallards. Initial analyses suggest that, in contrast to eastern and mid-continent mallards, annual reproductive success is not strongly density dependent. Environmental factors with the highest correlation to annual recruitment include spring precipitation and parameters related to agriculture in California.

Modeling Pintails - *Mike Runge*

The first step in developing an AHM process for pintails has been to develop a set of alternative models that represent the dynamics of the continental population. Efforts to model annual recruitment for pintails have focused on four areas of uncertainty thought to affect reproductive success: population density, population distribution, habitat conditions on the breeding range, and habitat conditions on winter locations. Annual productivity is indexed using age-ratios in the U.S. harvest. The initial recruitment model for pintails predicts annual reproductive success based on the average latitude of the breeding population, the size of the breeding population, and mean monthly precipitation (January-March) for the Prairie-Pothole region of Canada and the U.S. These three variables explain 57% of the historical variation in the index to recruitment. The average latitude of the breeding population is a better predictor of recruitment than the May ponds index, perhaps because it is a more direct measurement of the behavioral response of the birds to environmental conditions. Attempts to include a predictor related to wintering ground conditions have not been successful; further work is needed to identify appropriate candidate predictors. Efforts to model annual survival for pintails have focused on the uncertainty about whether the harvest is an additive or compensatory form of mortality. Analyses to estimate relationships between annual survival and additional factors, including population density, reproductive success, and habitat conditions, have been unsuccessful primarily due to the imprecision of annual survival rate estimates that is related to low harvest and recovery rates. A simple model of annual survival as a function of the kill rate, which closely follows the model of Johnson et al. (1997, JWM 61), was developed. Additive and compensatory models were parameterized by finding a value for survival in the absence of harvest that provided equally good fits to the historical data for both the additive and compensatory models. At the low level of harvest typical in recent years, these two models do not differ greatly in their predictions the practical importance of the differences to management has not yet been determined. Finally, there is some suggestion in the immature male survival data that some other important dynamic might be at work, but this has not yet been fully explored. At this time, it is proposed that this model set be adopted so that the next steps in the development of an AHM process for pintails can proceed.

Estimation of Band-reporting Rates for Mallards: 1998 Pilot Study - *Jim Kelley*

A pilot study was conducted in southern Saskatchewan in 1998 to obtain a preliminary estimate of band-reporting rates for adult mallards. The study was conducted in order to evaluate whether band-reporting rates have stabilized as a result of several years of implementation of the “1-800" number inscribed on bands. A total of 1,675 reward bands ($100.00 each) were put on adult mallards in three separate sites in southern Saskatchewan: Kindersley, Wynyard, Last Mt. Lake. A ratio of 2 standard (control) bands: 1 reward band was utilized.

The recovery rate for standard bands was 0.073 (S.E. 0.005), whereas the recovery rate for reward bands was 0.089 (S.E. 0.007). Based on these data, the estimate of the band-reporting rate is 0.826 (S.E. 0.082). This estimate is surprisingly high, however the 95% confidence interval was 0.664-0.987. Assuming that all reward bands are reported, the recovery rate of 0.089 for reward bands is also an estimate of the harvest rate of adult males banded in southern Saskatchewan. This estimate seems to fall well below the harvest rate of 0.13 expected under the liberal regulatory alternative. This discrepancy, if real, may be due to the fact that the predicted harvest rate of 0.13 accounts for mallards from the Great Lakes region, which have higher harvest rates than those from Saskatchewan. Plans for the 1999 pilot study are to broaden the area where reward bands are implemented to include the Great Lakes and other potential prairie areas. This will allow an estimation of harvest rates for mid-continent mallards that can be used in the adaptive management process.

The year of implementation of a full-scale reward band study that includes other species has not been determined as of yet. It is possible that the study could be conducted in 2000. This decision will depend on the assessment of whether band-reporting rates have stabilized and the ability of the Bird Banding Laboratory to provide consistent, high-quality processing of “1-800" phone calls in the coming years. Species that likely will be included in the full study are mallard, wood duck, black duck, and Canada goose. Input will be sought from the Flyway Council Technical Sections on this decision, especially with regard to Canada goose populations that should be targeted.

Modeling Mallard Harvests - *Mary Moore, Paul Padding, and Woody Martin*

Using historical data on mallard harvest and numbers of successful duck hunters (SDH) from 1970-1995, two models were developed to predict total seasonal mallard harvest for seven management areas: the northern Atlantic Flyway, the southern Atlantic Flyway, the Mississippi Flyway, the low plains portion of the Central Flyways, the High Plains Mallard Management Unit, the Pacific Flyway, and the Columbia Basin Mallard Management Unit. The “harvest” model utilized information on mallard bag limits and hunting season length to predict seasonal mallard harvest per SDH. The “hunter” model was developed to predict the number of SDH in each management area in a specific year under a specific set of hunting regulations (bag limit and season length). The predicted number of SDH was multiplied by the predicted seasonal harvest per SDH resulting in a predicted total mallard harvest (T) for a specific year. To compare T under different regulatory packages, ratios of T were formed. Under the assumption that the ratio of two harvest rates achieved under any 2 management options is equal to the expected ratio of total harvest obtained under the same 2 options, predicted harvest rates for regulatory options with which we have had little or no experience may be obtained by “adjusting” a harvest rate obtained under an experienced (base) package up or down by ratios of T. This method was used to obtain predicted harvest rates for the 1997 regulatory options. Model performance was assessed by comparing predicted total mallard harvest based on the 1996 regulatory packages with 1996 mallard harvest obtained from the Waterfowl Harvest Survey

(USFWS/MBMO Administrative Report, July, 1998). WHS mallard harvest point estimates for the Atlantic, Central, and Pacific Flyways, and the U.S. total (excl. AK) were all lower than the model predicted total harvest and fell below but were very close to the lower end of the 95% prediction interval. Although confidence intervals were not available for the WHS estimates, a ±95% CI of 11% on those estimates would have resulted in overlapping confidence/prediction intervals in all flyways. The WHS point estimate for the MF was well within the model based 95% prediction interval. Alternative models for predicting hunter numbers, which would eliminate the need for year-specific estimates, were presented for the purpose of discussion.

Changes in Mallard Harvests - *Paul Padding*

Recent changes in season length and bag limits have resulted in larger mallard harvests in each Flyway. Although most of the increases are due to greater harvest of males, female harvest has also increased, particularly in 1997 when the bag limit was raised to two hen mallards/day. The 1997 hen mallard harvest estimates are similar to those of the 1979-84 stabilized regulations period, the most recent period during which daily bag limits for hens were >1 in each Flyway. In comparison, recent (1995-97) harvests of male mallards are greater than they were during the 1979-84 period, except in the Central Flyway, where male harvest estimates for the two periods are similar.

Effects of Extended Framework Dates on Mallard Harvests in Iowa and Mississippi - *Khristi Wilkins*

We estimated the effect of extended framework dates in Iowa and Mississippi using an extension of a multivariate time-series analysis. The analysis involved three processes:

(1) regression of the treatment state's harvests to estimate the possible increase in the average annual harvest due to the framework extension;
(2) an analysis of the serial correlation in annual harvests; and
(3) inclusion of control states in the model to account for annual variation in harvests not attributable to the framework extension.

This analysis accounted for possible increases in harvest due to the framework extension, and for annual variation in harvest not due to the extension by using surrounding states in a multivariate graphical model. This analysis has the following advantages over the previous attempt:

(1) it accounts for lack of independence in harvest data over time;
(2) it matches states' harvest for the same years, rather than averaging treatment and non-treatment years in treatment and control states (analogous to a paired *t*-test); and
(3) it weights the effect of each surrounding state by its partial correlation coefficient, rather than assuming that each state reflects the annual variation in the harvest of the treatment state to the same degree.

The proportional changes in harvest attributable to the framework extensions in Iowa and Mississippi were not qualitatively different than those in our previous analyses (USFWS, 1998, Framework-date extensions for duck hunting in the United States, U.S. Dep. Inter., Washington, D.C. 43pp.), although the estimated magnitude of the effect changed for most species (note that the scale of β has changed from the first report such that β is now centered on zero rather than one). In Iowa, the framework extension appeared to increase ($P<0.02$) the annual harvests of six of the eight most important species in the bag. In Mississippi, the magnitude of the estimated harvest increases tended to be lower than in Iowa, and were significant ($P<0.1$) only for mallards and gadwall. We note that the estimated increase in mallard harvest in Mississippi is considerably lower than in our previous analysis.

More details of these analyses can be found on the Internet at www.fws.gov/r9mbmo/reports/reports.html.

Potential Impacts of Nationwide Framework Extensions on the Regulation of Mallard Harvests - *Fred Johnson*

Empirical analysis.--We determined the expected increase in total harvest of midcontinent mallards associated with framework dates extending approximately 10 days earlier and 10 days later than permitted under current regulatory alternatives. We assumed all states that held their seasons as early or late as possible during the 1997-98 season would take advantage of extended framework dates if they were offered). In practice, some of these states might not take advantage of extended framework dates, or would use them only with some regulatory alternatives or in some zones, but we had no basis for predicting such scenarios. Therefore, our analysis represents a worst-case scenario in terms of large-scale impacts.

In those states opening around 20 September, we assumed that mallard harvest would increase by 32.0 percent (SE = 14.2) compared with the current framework date of approximately 1 October. For states closing around 31 January, we assumed that mallard harvest would increase by 18.0 percent (SE = 11.3) compared with the closing framework date of approximately 20 January. We assumed no change (SE = 0) in harvest from current levels in states not expected to use extended framework dates and in Canada. The overall increase in harvest of midcontinent mallards was calculated by averaging the predicted change in harvest for individual states, using the proportion of band recoveries of midcontinent mallards occurring in each state as weights. Band recoveries were adjusted for sources of variation in reporting. The predicted increase in harvest of midcontinent mallards associated with 10-day extensions of opening and closing dates was 23.1 percent (SE = 4.4).

Optimization/simulation study.--We computed optimal harvest strategies for midcontinent mallards using methods described by Johnson et al. (1997, Uncertainty and the management of mallard harvests. J. Wildl. Manage. 61:203-217). We used an objective function to maximize long-term cumulative harvest, with a proportional devaluation of harvest when the size of the mallard population is expected to fall below the goal of the North American Waterfowl Management Plan. We also used the most current assessment of probabilities on four competing models of mallard population dynamics. We investigated the application of optimal strategies using Monte Carlo simulations, and evaluated expected performance using the mean of annual harvest and population size. We also tallied the frequency with which each of the four regulatory alternatives was used during the simulations, as well as the probability and magnitude of year-to-year regulatory changes.

We examined a range of possible harvest rates, bounded by those predicted under the current regulatory alternatives, and what might be realized under a nationwide extension of 10 days for both opening and closing dates in the moderate and liberal options. We also examined a range of harvest-rate variances from the current level of CV = 0.25 to CV = 1.0. For the purposes of this analysis, an increase in harvest-rate variance represents a decline in confidence regarding the ability to predict harvest rates associated with framework extensions. This decline in predictive ability reflects our uncertainty about whether the effects of extensions in Iowa and Mississippi are representative, and about what states would choose an extension if it were offered. We believe a two- to three-fold increase in harvest rate CV would be reasonable given our lack of experience with framework extensions.

Based on simulations of optimal harvest strategies, even small changes in harvest rate mean and variance can have significant impacts on regulatory strategies. With increases in mean harvest rate of the moderate and liberal alternatives, the expected frequency of liberal regulations declined, while that of the moderate and restrictive alternatives increased. The frequency of very restrictive regulations was not noticeably affected by increases in mean harvest rate. The probability of year-to-year regulatory changes also increased with increased harvest-rate means, although the magnitude of annual changes was largely unaffected. Results associated with increases in the variance of harvest rates were also consistent with more conservative harvest strategies. Although the frequency of liberal regulations was relatively insensitive to increased variances, the expected frequency of restrictive regulations increased dramatically, at the expense of the moderate alternative.

Interestingly, mean annual harvest and population size were not sensitive to increases in the mean harvest rate of the moderate and liberal options. These results reflect the compensatory effect of the more conservative strategies associated with increases in harvest rate. Increases in the variance of harvest rates led to significant decreases in average harvest and increases in average population size, reflecting a dramatic increase in the frequency of restrictive regulations.

More details of these analyses can be found on the Internet at www.fws.gov/r9mbmo/reports/reports.html.

Position Statement on Framework Extensions - *Working Group*

AHM is an effective tool for making decisions in the face of biological uncertainty, but only if there is broad-based agreement on management objectives (i.e., how to value harvests, and how those values should be shared). In this light, framework extensions are problematic not because of any shortcoming of AHM, but because of tacit disagreement over desirable allocations of harvest or harvest opportunity. Therefore, the Working Group emphasizes that resolution of the framework-date issue cannot be found in the technical or biological constructs of AHM.

Both the National Flyway Council (NFC) proposal and the USFWS guidelines do not provide sufficient detail to permit an assessment of optimal harvest strategies and expected performance (e.g., we would need to know not only how many states would select an extension, but which ones). In the case of certain regulatory specifics (e.g., framework-date restrictions in the Very Restrictive alternative, and bag-limit restrictions during an opening extension), the Working Group believed that there was little or no basis for empirical assessments. An evaluation of the NFC and USFWS scenarios based on other criteria (e.g., hunter satisfaction, acceptance among administrators, "fairness") seemed beyond the purview of the Working Group.

Without additional information, the assessment recently conducted by the U.S. Fish & Wildlife Service (for the Senate Committee on Appropriations) likely represents the best that can be done. That assessment effectively determines an upper bound to impacts on mallards and associated harvest strategies, assuming that 10-day framework extensions (both opening and closing dates) were offered nationwide with no penalties. That assessment also demonstrates patterns in optimal harvest strategies and expected performance characteristics that can be used to help evaluate proposals that extend frameworks in a small portion of the country, or that contain season-length and bag-limit penalties.

There are *no* cost-free alternatives. Even "harvest-neutral" proposals that greatly increase the uncertainty associated with predicted harvest levels have impacts on optimal harvest strategies. Generally, these impacts involve more conservative, and more "knife-edge" strategies (i.e., frequent regulatory changes of large magnitude) for all states in all Flyways.

The Working Group remains concerned that we are ill-equipped to predict and assess the impacts of extended framework dates, other than impacts on levels of midcontinent mallard harvest. Impacts on local populations, on other species, and on subsequent reproductive performance remain largely speculative. Nonetheless, the management community is urged to consider the full range of potential biological impacts associated with framework extensions.

If AHM is to remain a viable tool for informed decision making, the Working Group believes that any proposal should adhere to the following guidelines:

(1) any change to the set of regulatory alternatives should increase the probability that the set will remain stable long enough to observe the ranges of realized harvest rates; this is essential for understanding the impact of regulations on harvest, and of harvest on population size;

(2) proposals with minimal complexity are preferred (i.e., fewer rules or special cases); complexity decreases our ability to predict and evaluate impacts, and may decrease the chance of stability;

(3) because of our limited experience with framework extensions, the same set of regulatory alternatives (i.e., framework dates, season lengths, bag limits) should be applicable to an entire Flyway (or established management unit); regulatory alternatives that differ among states within a Flyway greatly decrease our ability to predict and evaluate regulatory impacts, and set the stage for further refinement in duck harvest management that currently cannot be supported technically;

(4) regulatory proposals that move us away from experience should be done methodically and incrementally; large departures from experience do not permit informed regulatory decisions and, thus, undermine the intent of AHM;

(5) major changes to the set of regulatory alternatives always should be accompanied by a mechanism for empirical feedback; therefore, expansion of the reward-band pilot study is imperative if changes are to be made before the full reward-band study is completed.

Based on these considerations, the Working Group reiterates its longstanding position that the set of regulatory alternatives should not be changed without compelling reason and broad-based support. At this time, the Working Group continues to support the set of alternatives that was developed in 1997.

If the management community feels compelled to extend framework dates beyond those in the 1997 alternatives, the Working Group believes that the following scenarios are consistent with our ability to use AHM as a tool to inform decision making. These scenarios should not be construed as proposals, but simply reflect the Working Group's desire to maintain the integrity of AHM, should framework extensions be considered.

(1) maintain the set of regulatory alternatives established in 1997, but include a January 31 closing date for the lower Mississippi Flyway in the Liberal alternative, as long as it is accompanied by a 9-day reduction in season length; or

(2) use the 1997 alternatives with an adaptive approach to framework extensions; this would involve framework dates of September 23 to January 31 in the Liberal alternative with no penalties; initially, the optimal strategy would account for competing hypotheses, equally weighted, reflecting no harvest impact and the maximal impact described in the Service's recent assessment; in subsequent years, harvest strategies would be adjusted based on empirical observations of realized harvest rates; in the short term, potential impacts on other species would have to be considered by way of species-specific bag limits; in the longer term, any harvest increases for all ducks would be offset (at least partially) by more conservative strategies.

The following tables are intended to inform debate about these and other alternatives. All strategies assume 1998 model weights. For all tables, 0=Closed, 1=Very restrictive, 2=Restrictive, 3=Moderate, and 4=Liberal.

Table 1. The optimal strategy for the 1997 regulatory alternatives, which also would apply to the 1998 regulatory alternatives. This strategy assumes 1998 model weights.

Bpop (M)	Regulatory alternative*												
	Canadian ponds (M)												
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0
3.5	0	0	0	0	0	0	0	0	0	0	0	0	0
4.0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.5	0	0	0	0	0	0	0	0	0	0	0	0	0
5.0	0	0	0	0	0	0	0	0	0	0	0	1	1
5.5	0	0	0	0	0	0	0	1	1	1	1	2	2
6.0	0	0	0	1	1	1	1	1	2	2	2	3	3
6.5	1	1	1	1	1	1	2	2	3	3	4	4	4
7.0	1	1	2	2	2	2	3	3	4	4	4	4	4
7.5	2	2	2	3	3	3	4	4	4	4	4	4	4
8.0	3	3	3	3	4	4	4	4	4	4	4	4	4
8.5	3	3	4	4	4	4	4	4	4	4	4	4	4
9.0	4	4	4	4	4	4	4	4	4	4	4	4	4
9.5	4	4	4	4	4	4	4	4	4	4	4	4	4
10.0	4	4	4	4	4	4	4	4	4	4	4	4	4
10.5	4	4	4	4	4	4	4	4	4	4	4	4	4
11.0	4	4	4	4	4	4	4	4	4	4	4	4	4
11.5	4	4	4	4	4	4	4	4	4	4	4	4	4

*0=Closed, 1=Very restrictive, 2=Restrictive, 3=Moderate, and 4=Liberal

Table 2. The optimal strategy assuming that most states would make full use of a 10-day extension of opening and closing dates in the Liberal alternative (with no penalty), and assuming that harvest impacts would be similar to those observed historically in Iowa and Mississippi. This strategy assumes 1998 model weights.

Bpop (M)	Regulatory alternative*												
	Canadian ponds (M)												
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0
3.5	0	0	0	0	0	0	0	0	0	0	0	0	0
4.0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.5	0	0	0	0	0	0	0	0	0	0	0	0	0
5.0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.5	0	0	0	0	0	0	0	0	0	1	1	1	1
6.0	0	0	0	1	1	1	1	1	1	1	1	2	2
6.5	1	1	1	1	1	1	1	2	2	2	2	3	3
7.0	1	1	1	2	2	2	2	2	3	3	3	3	4
7.5	2	2	2	2	3	3	3	3	3	4	4	4	4
8.0	2	3	3	3	3	3	3	4	4	4	4	4	4
8.5	3	3	3	3	3	4	4	4	4	4	4	4	4
9.0	3	3	3	4	4	4	4	4	4	4	4	4	4
9.5	3	4	4	4	4	4	4	4	4	4	4	4	4
10.0	4	4	4	4	4	4	4	4	4	4	4	4	4
10.5	4	4	4	4	4	4	4	4	4	4	4	4	4
11.0	4	4	4	4	4	4	4	4	4	4	4	4	4
11.5	4	4	4	4	4	4	4	4	4	4	4	4	4

*0=Closed, 1=Very restrictive, 2=Restrictive, 3=Moderate, and 4=Liberal

Table 3. An optimal adaptive strategy with framework extensions in the Liberal alternative only, and in which there is equal weight on competing hypotheses of no and maximal harvest impacts of large-scale extensions. This strategy assumes 1998 model weights.

Bpop (M)	Regulatory alternative*												
	Canadian ponds (M)												
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0
3.5	0	0	0	0	0	0	0	0	0	0	0	0	0
4.0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.5	0	0	0	0	0	0	0	0	0	0	0	0	0
5.0	0	0	0	0	0	0	0	0	0	0	0	0	1
5.5	0	0	0	0	0	0	0	0	1	1	1	1	1
6.0	0	0	0	1	1	1	1	1	1	1	2	2	3
6.5	1	1	1	1	1	1	2	2	2	3	3	3	3
7.0	1	1	1	2	2	2	2	3	3	3	4	4	4
7.5	2	2	2	2	3	3	3	3	4	4	4	4	4
8.0	2	3	3	3	3	3	4	4	4	4	4	4	4
8.5	3	3	3	3	4	4	4	4	4	4	4	4	4
9.0	3	3	4	4	4	4	4	4	4	4	4	4	4
9.5	4	4	4	4	4	4	4	4	4	4	4	4	4
10.0	4	4	4	4	4	4	4	4	4	4	4	4	4
10.5	4	4	4	4	4	4	4	4	4	4	4	4	4
11.0	4	4	4	4	4	4	4	4	4	4	4	4	4
11.5	4	4	4	4	4	4	4	4	4	4	4	4	4

*0=Closed, 1=Very restrictive, 2=Restrictive, 3=Moderate, and 4=Liberal

Table 4. The optimal adaptive strategy as above, except that the extensions are contained in both the Liberal and Moderate alternatives. This strategy assumes 1998 model weights.

Bpop (M)	Regulatory alternative*												
	Canadian ponds (M)												
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0
3.5	0	0	0	0	0	0	0	0	0	0	0	0	0
4.0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.5	0	0	0	0	0	0	0	0	0	0	0	0	0
5.0	0	0	0	0	0	0	0	0	0	0	0	0	1
5.5	0	0	0	0	0	0	0	0	1	1	1	1	1
6.0	0	0	0	1	1	1	1	1	1	1	2	2	2
6.5	1	1	1	1	1	1	1	2	2	2	3	3	3
7.0	1	1	1	2	2	2	2	2	3	3	3	4	4
7.5	2	2	2	2	2	3	3	3	4	4	4	4	4
8.0	2	2	3	3	3	3	3	4	4	4	4	4	4
8.5	3	3	3	3	3	4	4	4	4	4	4	4	4
9.0	3	3	3	4	4	4	4	4	4	4	4	4	4
9.5	3	4	4	4	4	4	4	4	4	4	4	4	4
10.0	4	4	4	4	4	4	4	4	4	4	4	4	4
10.5	4	4	4	4	4	4	4	4	4	4	4	4	4
11.0	4	4	4	4	4	4	4	4	4	4	4	4	4
11.5	4	4	4	4	4	4	4	4	4	4	4	4	4

*0=Closed, 1=Very restrictive, 2=Restrictive, 3=Moderate, and 4=Liberal

Table 5. Expected performance characteristics of the optimal strategies contained in the above tables. Regulation level is the expected average of annual regulation levels, where 0=Closed, 1=Very restrictive, 2=Restrictive, 3=Moderate, and 4=Liberal. Harvest utility is the average of annual midcontinent mallard harvests (in millions), which have been devalued whenever population size fell below the NAWMP goal. Population size is the average annual breeding population size of midcontinent mallards, including the three Lake States (in millions). Regulatory frequency is the percentage of years in which different regulatory alternatives are expected (note that although no closed seasons are expected, simulations do not account for the full range of potential environmental variation). The last column is the probability of a change in regulatory alternative from one year to the next. Expected performance characteristics assume 1998 model weights.

Strategy (Table #)	Regulation level (CV)	Harvest utility (CV)	Population size (CV)	Regulatory frequency (%) (L / M / R / VR)	Probability (%) of annual reg. change
Default (1)	3.52 (0.19)	1.33 (0.36)	8.13 (0.10)	64 / 24 / 12 / 0	40
Worst-case (2)	3.12 (0.22)	1.34 (0.45)	8.01 (0.07)	30 / 53 / 16 / 1	48
Adaptive [L] (3)	3.40 (0.22)	1.40 (0.41)	8.16 (0.08)	55 / 31 / 13 / 1	41
Adaptive [M&L] (4)	3.31 (0.22)	1.44 (0.39)	8.21 (0.07)	46 / 39 / 15 / 0	50

Meeting Action Items - *Working Group*

Communication workshop.--Three action items relative to Postulate #1 were discussed by the Working Group:

(1) A subcommittee within the Working Group (Humburg, Johnson, Case, Otto, Padding, and possibly with assistance of former member Jim Ringelman) is to define the objectives of a waterfowl hunter survey that would help incorporate measures of hunter satisfaction into considerations for harvest management. Follow-up work would be needed to determine legal or other constraints, to identify a task force to develop the survey, and ultimately to determine how or whether to incorporate information about hunter satisfaction into harvest management decisions.

(2) The Flyway Representatives have the lead in documenting the historic pattern of regulations and harvest, and the relationship between the regulations process and harvest management decisions. The latter aspect was oriented towards documenting the debate that led to key changes in the nature of harvest management. For example, what was the impetus, information used, and arguments for regulations such as the point system, ½-hour before sunrise shooting hours, zones/splits, frameworks changes etc. The feeling was that

documentation of the history of harvest and harvest management decisions would provide a shared reference for things that currently are "common knowledge."

(3) The Working Group discussed the value of a session dedicated to AHM at the joint Flyway Council meeting in Memphis in July, 2000. With regard to items (1) and (2) above, it might be an excellent opportunity to inform and develop greater ownership in the process (both successes and challenges). Also discussed was whether this joint meeting would be a good springboard for a "harvest management forum," in which a dialogue about harvest-management objectives, particularly as they relate to harvest allocation, could be structured and pursued.

Updating model weights.--Bill Kendall will discuss the updating procedure with Mike Conroy to ensure that it has provided reasonable results, particularly in 1997. Bill also will explore methodology to incorporate the sampling variances of regression coefficients in recruitment and survival models.

Modeling midcontinent mallards.--Jim Dubovsky will solicit peer review of his recent recruitment model. Jim also will make arrangements to report his work to the Flyway Councils, so that a change to the current model set can be considered for next year. Bill Kendall will continue his investigation of mallard survival, focusing on the methodology necessary to associate rates of natural mortality and environmental conditions. However, Bill should conduct an exploratory analysis, which would entail direct estimation of natural mortality rates, and use of these estimates in standard regression procedures. This analysis would help formulate hypotheses for more formal testing.

Eastern mallards.--Fred Johnson will continue efforts to examine the difference between mallard population sizes predicted from the current “working model” and those from the aerial and plot surveys. Fred also should report recent investigations of AHM protocols for eastern mallards to the Atlantic Flyway Council this summer.

Reward banding.--Jim Kelley and Graham Smith will determine needs and plans for a continuation of the pilot study in 1999. The focus of the 1999 study will be to help assess temporal changes in band-reporting rate, and to estimate the harvest rate of midcontinent male mallards. Jim and Graham also will begin to communicate with the Flyway Councils regarding the design and costs of the full reward-band study scheduled for 2000 or later.

Evaluation of proposed regulatory alternatives.--The Working Group assumes responsibility for assessing the potential impact of proposed regulatory alternatives on the harvests of various mallard stocks. The responsibility for assessing potential impacts on species other than mallards should remain with the Flyway technical sections, the Office of Migratory Bird Management, and other traditional partners.

Expected performance of current regulatory alternatives.--Dale Humburg has the lead in examining various performance measures (e.g., probability of closed and very restrictive seasons, frequency of regulatory changes) associated with the current set of regulatory alternatives. Staff from the Office of Migratory Bird Management will provide assistance as needed.

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ADAPTIVE HARVEST MANAGEMENT WORKING GROUP
Meeting Agenda

<u>Tuesday, April 13th:</u>

☞ Introductory remarks - *Bob Blohm*

☞ AHM implementation: status and issues- *Fred Johnson*

☞ AHM status reports
- ! Pacific Flyway - *Jeff Herbert, Dan Yparraguirre, & Bob Trost*
- ! Central Flyway - *Mike Johnson, Jim Gammonley, and Dave Sharp*
- ! Mississippi Flyway - *Dale Humburg, Scott Baker, & Ken Gamble*
- ! Atlantic Flyway - *Bryan Swift, Gary Costanzo, & Jerry Serie*
- ! Canadian Wildlife Service - *Dale Caswell*
- ! U.S. Fish & Wildlife Service - *Bob Blohm*

☞ Adaptive management of black ducks - *Mike Conroy*

☞ Computing algorithms for adaptive management - *Clint Moore*

☞ Communications update & breakout session - *Dave Case and Communications Team*

<u>Wednesday, April 14th:</u>

☞ Midcontinent mallards
- ➤ Current conditions and outlook for breeding waterfowl - *Jim Dubovsky*
- ➤ Posterior model probabilities - *Bill Kendall*
- ➤ Modeling survival - *Bill Kendall*
- ➤ Modeling reproduction - *Jim Dubovsky*
- ➤ Assessing the effect of habitat on the midcontinent mallard population - *Rex Johnson*

☞ Eastern mallards
- ➤ Modeling update - *Gary Costanzo*
- ➤ Integration with midcontinent mallards - *Fred Johnson*

☞ Western mallards
- ➤ Modeling update - *Sue Sheaffer*

☞ AHM for pintails - modeling update - *Sue Sheaffer*

<u>Thursday, April 15th:</u>

☞ Regulatory alternatives
- ➤ Estimating realized harvest rates - *Jim Kelley*
- ➤ Modeling mallard harvests: model validation & hunter #'s - *Mary Moore*
- ➤ Changes in mallard harvests - *Paul Padding*
- ➤ Effects of framework extensions in Iowa & Mississippi - *Khristi Wilkins*
- ➤ Potential impacts of large-scale framework extensions - *Fred Johnson*
- ➤ Working session for framework dates
- ➤

<u>Friday, April 16th:</u>

☞ Meeting synthesis (key messages, action items, communication strategy)

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