The Problem of Scale in Adaptive Harvest Management: Alternatives for Recognizing Stock-Specific Variation in Harvest Potential

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Introduction

Since its inception, the Adaptive Harvest Management (AHM) program has focused on the population dynamics and harvest potential of mallards, primarily those breeding in midcontinent North America. Midcontinent mallards constitute a large portion of the total U.S duck harvest and traditionally have been a reliable indicator of the status of many other species. However, not all duck stocks (i.e., species and populations) have the same potential as midcontinent mallards to support harvest. Moreover, in recent years there has been a growing disparity between midcontinent mallards and some duck stocks in population status. Therefore, the purpose of this document is to describe possible approaches for explicitly recognizing the differences in the ability of various duck stocks to support sustainable levels of harvest. To facilitate understanding and discussion, several conceptual alternatives for incorporating multiple species and Flyway-specific regulatory choices in the decision-making protocols for AHM are provided.

We begin by framing this discussion in terms of the larger strategic issue of management scale, which involves two related questions:

> *How does the harvest potential of ducks (i.e., the ability of ducks to support sustainable harvests) vary over time, space, and with level of ecological organization (e.g., population or species)?*
>
> *How should managers promulgate regulations in light of these differences to best address harvest-management goals, objectives, and constraints?*

The answer to the first question can be derived solely from the application of biological science, while the answer to the second depends on how the public values duck abundance, the magnitude and distribution of hunting opportunity, and the complexity of hunting regulations (as well as the inevitable and difficult tradeoffs among them).

Not surprisingly, the appropriate scalar resolution of duck harvest management has been debated for decades, and it was a dominant theme of the last environmental impact statement on migratory bird hunting (U.S. Fish and Wildlife Service 1988). A comprehensive solution remains elusive, however, not just because of the complexity and uncertainty in ecological systems, but because of continuing ambiguity in the social values and tradeoffs that are inherent in harvest management. We expect that

the resolution of this ambiguity will take some time, and will depend on strategic, policy-oriented discussions throughout the waterfowl management community. The anticipated AHM Task Force can help frame and facilitate these discussions and, once the Task Force has been appointed, a consultation process and schedule needs to be developed. In the meantime, this document is intended to begin the dialogue about some of the most important scale issues.

Although this document is of a technical nature and intended for the waterfowl management community, we recognize that the implications of alternative approaches will be of great interest to waterfowl hunters. We believe that recognition and, to the extent possible, accommodation of hunters' opinions and concerns will be an essential part of any viable solution to the problem of management scale.

The conceptual alternatives described herein are intended only to illustrate what we believe to be the range of possible approaches and, as such, are intended to identify and contrast key features. It is entirely possible that none of the alternatives as described is acceptable. If so, our hope is that discussion of the alternatives will lead to other, more viable ones. In any case, it seems clear that there is insufficient time for consultation, identification of a preferred approach, and modification of the AHM protocols prior to the 2003 hunting season. Incremental progress may be possible, however, to the extent that the preferred conceptual approach can be anticipated. In addition, *ad hoc* regulatory restrictions for species or populations of special concern always are an option, particularly during the transition to a more comprehensive multiple-species approach. By *ad hoc* we mean "as a special case;" we do not imply, nor do we advocate, regulatory strategies that lack the fundamental elements of AHM (i.e., unambiguous objectives, agreed-upon regulatory alternatives, an assessment of population dynamics, and mechanisms for coping with management uncertainties).

Development of Scaling Alternatives for AHM

In developing the alternatives described herein we assumed that the goals of the management community are principally twofold. The first is to optimize long-term harvest returns by accounting for species differences in harvest potential, whereby no species in question is either "over-harvested" or "under-harvested." Here the principal concern appears to be with reducing the perceived conservation risk to species other than mallards represented by the current AHM protocol. The second goal is to enhance Flyway-based harvest management, whereby the regulatory choice could vary among Flyways to account for each Flyway's unique breeding-ground derivation of ducks. Of course, no Flyway receives ducks exclusively from one breeding area, and so Flyway-specific harvest strategies ideally must account for multiple breeding stocks that are at least partially exposed to a common harvest.

The addition of these goals will require more complexity in the key components of the AHM process: the objective function(s), biological models, set of regulatory alternatives, and monitoring program. At a minimum, the objective function(s) and models of population dynamics will need to be modified. Moreover, in order to make the approach adaptive, we must be able to make alternative predictions about the effects of a particular regulatory strategy (in terms relevant to the stated management objectives), and then observe the realized effects (through the monitoring program) to

identify the most accurate predictions. There are likely to be numerous uncertainties about regulatory effects as yet unconsidered when we account for the population dynamics of ducks other than mallards. The key uncertainties need to be identified and provisions made for updating predictions in accordance with resource-monitoring capabilities. Finally, we probably should consider whether the current set of regulatory alternatives (or "packages") can best meet our expanded goals. Therefore, we propose to evaluate both the current (1997-2002) and original (1995-1996) set of regulatory packages in exploring the implications of scaling alternatives. Other combinations of season length, bag limits, and framework dates may have to be considered as the planned review of regulatory packages is conducted by the AHM Task Force.

To begin to narrow the range of possible approaches to scaling AHM, we considered the various degrees of stratification in regulations on spatial, temporal, and organizational scales that might be deemed acceptable. On a spatial scale, we assumed that a nationwide application of a particular regulatory alternative is unacceptable, and that regulatory decisions should be allowed to vary among at least some Flyways. For the moment, we ruled out finer-grained spatial stratifications, in which regulatory decisions could vary on a sub-Flyway basis. For example, both the High Plains Mallard Management Unit and the rest of the Central Flyway would share the same regulatory alternative (although season length would be different).

On the temporal scale, regulations currently are stratified by year but other approaches are possible. For example, there has always been at least some interest in "stabilized" regulations, whereby a regulatory alternative would remain in effect for a predetermined number of years or until some specified event precipitated a change. Another perspective involves intra-year regulatory decisions. For example, we might consider the Special September Teal Season and the regular season within the same decision-making framework. For the purposes of this exercise, however, we considered only annual decision making. In doing so, however, we recognize that it may be desirable to achieve some stability in regulations among years. This goal can be met by discounting the value of regulatory decisions that are different from the previous year. This mechanism could be incorporated in any approach to species- and Flyway-specific regulatory strategies.

Perhaps the most difficult choices involve stratification of regulations on an organizational scale. Here we are talking about the extent to which season lengths, bag limits, and framework dates are stock-specific. At the coarsest scale, we would have one season length, one bag limit, and one set of framework dates for all ducks. At the other extreme, regulations could vary for each ecological unit (e.g., species or sex) that is identifiable by the hunter. A key focus of traditional stock-specific management efforts has been at the species level. Species-specific bag limits have a long history, and have been used primarily in an attempt to restrict the harvests of species thought to be unable to support the maximum bag limit set for ducks in the aggregate. During the 2000-01 hunting season, there were species-specific bag-limit restrictions for at least ten duck species. Other historic approaches to species-specific harvest management include "bonus bag limits" and the "point system." The efficacy of these regulatory approaches for regulating species-specific harvests has not been rigorously studied (Nichols and Johnson 1989), but in at least some cases it has been demonstrably poor (Rexstad et al. 1991, Johnson and Moore 1996). More recently, short season lengths within the overall duck season (so-called "season within a season") have been used for some

species whose population status was of concern (e.g., black ducks, canvasbacks, pintails). Species-specific season lengths tend to be more effective than bag limits at regulating species-specific harvests.

For the purposes of this document, we restricted our attention to populations of conspecifics as the minimum ecological unit (although we recognize that sex-specific harvesting is occasionally of interest). To narrow the range of possible approaches to species-specific management, we believe managers must address the following questions:

(1) For which species (or group of species), if any, would independent season lengths (and possibly bag limits and framework dates) be acceptable?
(2) For which species (or group of species), if any, would only independent bag limits (fixed or varying annually) be acceptable (assuming that season length for these species is specified based on some unrelated group of birds)?
(3) For which species (or group of species), if any, would periodic closed seasons be acceptable (assuming that season length and bag limits for these species were specified based on some unrelated group of birds)?

We demonstrate some possible answers to these questions in the following alternatives. The alternatives were constructed by relying on the conceptual framework provided in Appendix A, which we encourage the reader to review before proceeding. We emphasize that the alternatives are designed primarily to help demonstrate and contrast various approaches for dealing with the problem of scale. We discourage the reader from "voting" for a particular alternative at this time because the ultimate approach might well need to be different from any of these alternatives.

Alternative A

This alternative involves continuing the current AHM protocols based on mallards, but devaluing mallard harvests associated with regulatory decisions that are expected to result in population levels of other species below their goals in the North American Waterfowl Management Plan (NAWMP). This is similar in concept to the current approach for midcontinent mallards, in which regulation-specific mallard harvests are devalued if the decision is expected to produce a subsequent population size below the NAWMP goal for midcontinent mallards. The devaluation of harvest works in such a way as to decrease the likelihood that regulatory choices that contribute to the maintenance or reduction of the population level below its goal will be considered optimal. As in the current process for midcontinent mallards, the degree of devaluation would be conditional on not only the breeding-population level of other species (relative to their goals), but also on their anticipated reproduction and natural mortality prior to the subsequent breeding season.

This approach would be phased in gradually to accomplish the goal of Flyway-based management. In the first phase, the constraint based on the status of other species would be introduced into the two existing optimization processes for midcontinent and eastern mallards (Fig. 1A). At least initially, the constraint would be based on the status of the nine other principal species breeding in the midcontinent region (gadwall, American wigeon, green-winged teal, blue-winged teal, northern

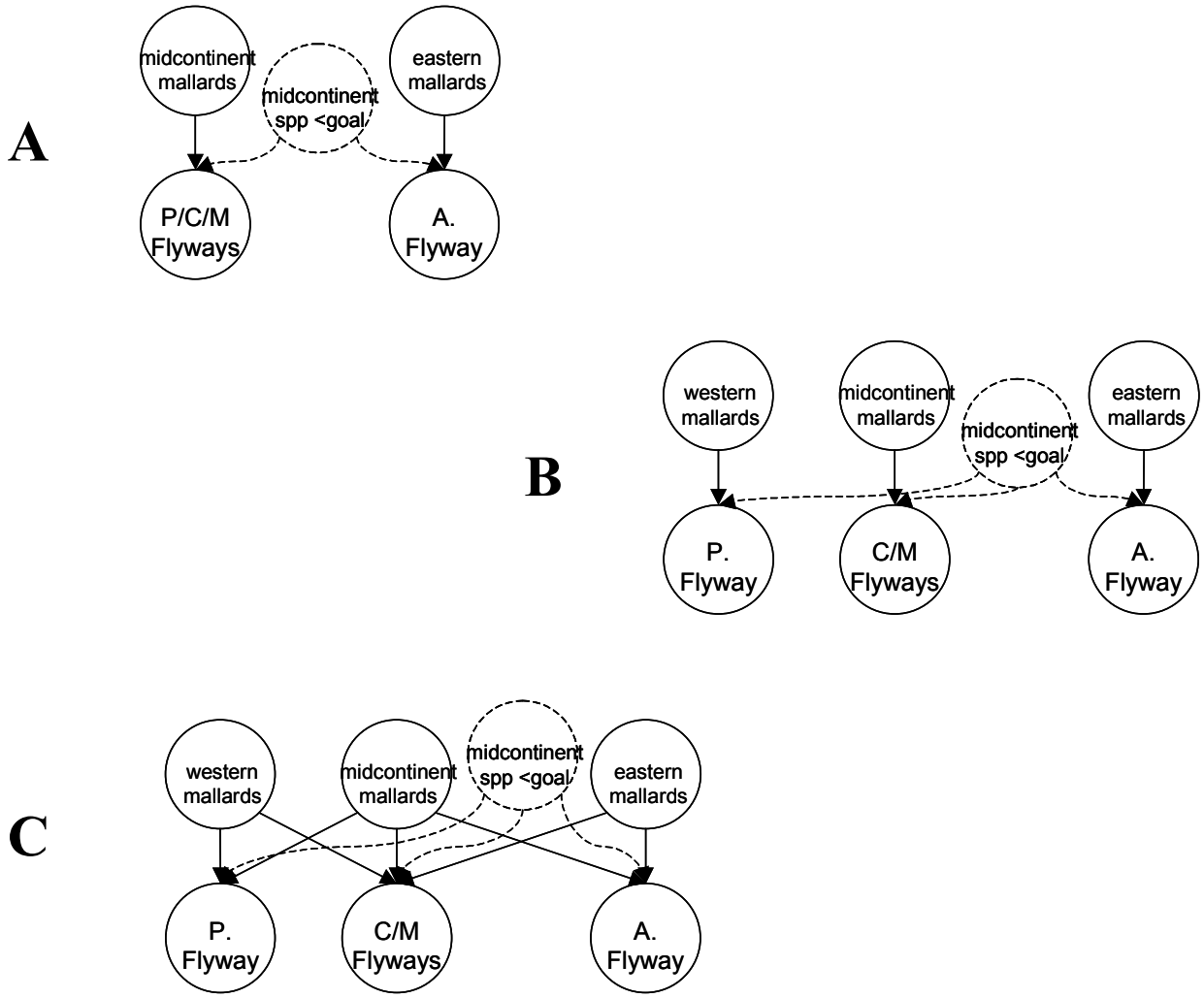

Fig. 1. A constraint on the optimization of mallard harvests based on the number of midcontinent duck species below their population goals of the NAWMP. A, B, and C represent a phasing in of key stocks of mallards and how they distribute themselves among the Flyways.

shoveler, northern pintail, redhead, canvasback, and scaup). The constraint would be applied to all Flyways because all Flyways share the harvest of these nine midcontinent species.

In the second phase, a western stock of mallards would be introduced and used to determine the optimal regulatory choice for the Pacific Flyway (Fig. 1B). All Flyways would still be subject to the constraint based on the nine midcontinent species. In the final phase, we would no longer assume that the three stocks of mallards are closed populations, and efforts would be made to model emigration and immigration (Fig. 1C). The explicit recognition of these movements would require that the regulatory choices be jointly (simultaneously) optimized for all harvest areas and, thus, objectives for harvest distribution would have to be articulated.

The devaluation of mallard harvest might depend on the number of species below their NAWMP goals. In what is likely to be the simplest case, there would be three classes of population status: (1)

below goal; (2) at goal; and (3) above goal. Bounds would be specified to determine whether a species was "at" goal (perhaps based on the sampling variances of population estimates). Only two state variables (i.e., decision criteria) would be added to the current mallard optimizations, representing the observed number of species in two of the three classes (the number in the other class could be derived by subtraction) in year *t*. The challenge would be to produce a dynamic model (or alternative models) that could predict (probabilistically) the number of species in each class in year *t*+1, based on the observed number in each class, the observed number of ponds (as a predictor of reproductive success), and a given regulatory choice in year *t*. Each of the species predicted to be at or above goal in the subsequent year would be assigned a value of one. Each of the species predicted to be below goal in the subsequent year would be assigned a value of zero. The species' values then would be summed, and the harvest devalued (as specified in a utility function, Fig. 2) whenever the sum was less than nine. The ability to add only two state variables to the mallard optimizations would depend on the development of a dynamic population model (or alternative models) that specified probabilities of transition among classes that were *not* species-specific (preliminary analyses suggest this may be the case). Otherwise, the number of state variables would have to be increased to account for differences among species in transition probabilities (which in turn could lead to computational difficulties in the optimization).

The details of the harvest devaluation are somewhat complex, but the concept it represents is simple. The proposed approach expresses the idea that it is the number of species below their NAWMP goals that is of primary concern (rather than the magnitude of the difference between population size and the NAWMP goal). The degree to which the number of species below goal constrained regulatory choices for mallards would depend on the specified form of the utility function, and a number of alternative forms could be explored to help inform this subjective decision (Fig. 2). Finally, the

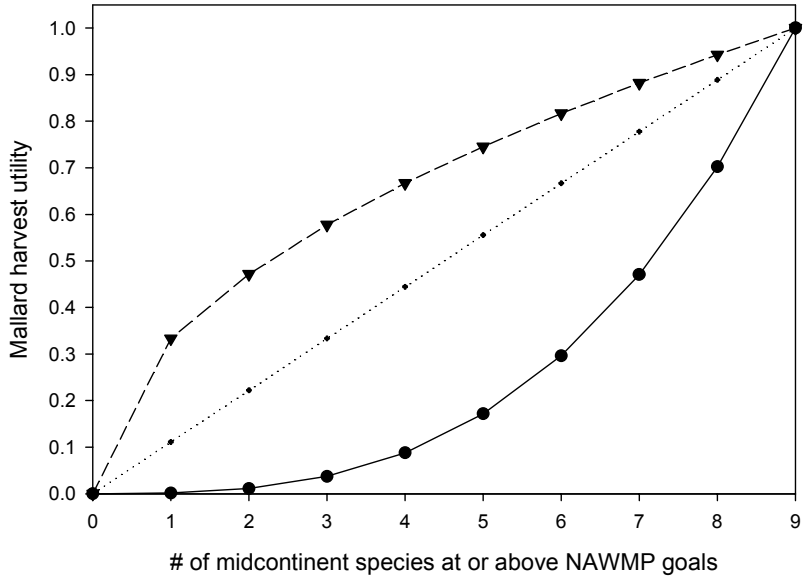

Fig. 2. Possible devaluations of mallard harvest based on the number of other species at or above their NAWMP goals.

proposed approach gives equal weight to the nine species, and does not permit species above goal to somehow "compensate" for those below goal.

An important feature of Alternative A is the ability to have independent seasons or bag limits (including season closures) for species of special concern. For example, if the constraint on mallard-based regulations was deemed inadequate to protect pintails, then that species could be removed from the set of nine. A separate optimization process would be employed, in which season lengths and bag limits for pintails would be set independently of those for other ducks. It would be important to determine appropriate criteria for specifying species to be treated in this way. Such criteria probably would include whether there was a long-term decline in abundance, whether hunters had the ability to identify the species in flight, and whether the additional complexity in regulations was worth the perceived benefits. Possible candidates are pintails, canvasbacks, and black ducks. Species for special treatment would not have to be specified *a priori* but on an as-needed basis. However, we emphasize that this *ad hoc* approach may be difficult to administer and could well lead to a proliferation of species-specific seasons.

Alternative B

Alternative B is based on the idea of a species guild, which we use here to mean a group of duck species with similar harvest potentials. The key feature of this alternative is that each guild would be the subject of an independent optimization process, whereby the choice of regulatory alternative could vary by guild. For the sake of discussion, we propose only two guilds - one comprised of species with relatively high harvest potentials and the other comprised of species with relatively low harvest potentials. The goal is to take advantage of the hunting opportunity afforded by relatively productive species, while protecting those species where harvest may be more of an issue in species management. For the purposes of this exercise, we focused solely on the ten principal species in the midcontinent region, although we recognize that some other key species (e.g., wood ducks, black ducks) ultimately would have to be accommodated.

It is difficult to assess the harvest potential of a species directly, so we considered a number of surrogate measures for grouping species into guilds. Initially, we calculated inter-species correlations in annual growth rates and used these as measures of similarity in a cluster analysis (Fig. 3). Some of the groupings made intuitive sense (e.g., mallards and blue-winged teal, wigeon and green-winged teal), while others were more difficult to explain (e.g., shovelers and pintails). Consequently, we did not believe that these results provided a compelling basis to divide species into two guilds.

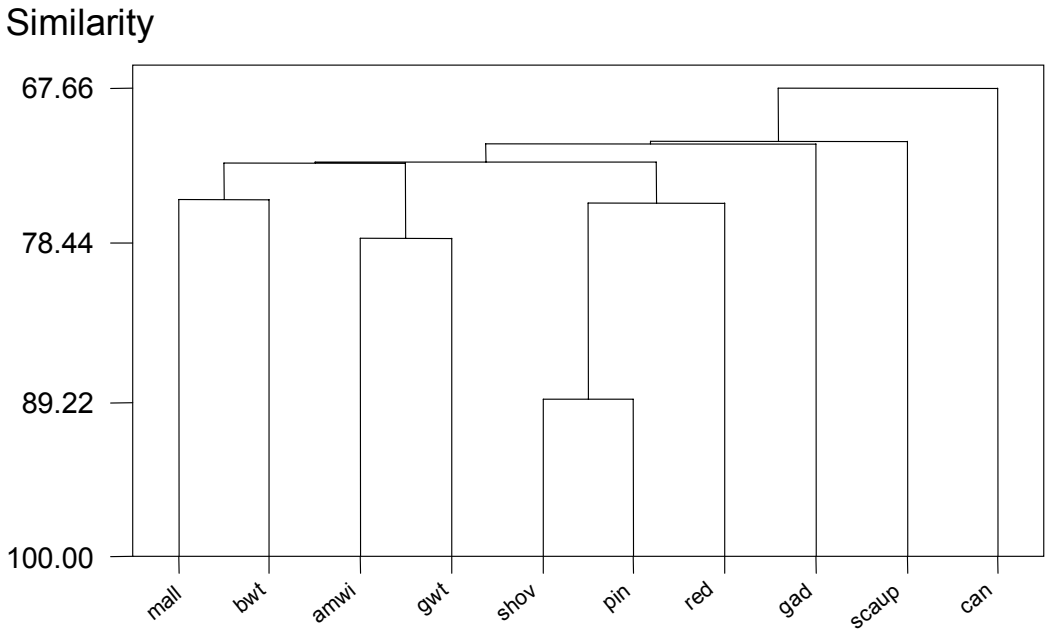

Fig. 3. Cluster dendrogram of the ten principal species in the midcontinent region based on inter-species correlations in annual growth rates.

We subsequently relied on life-history characteristics (Patterson 1979, Bailey 1981), similarities in survival rates (Krementz et al. 1997) and harvest age ratios (M. Otto, U.S. Fish and Wildlife Service, unpubl. data), current status relative to NAWMP goals, and long-term population trends to specify the two guilds:

Guild 1 ("high" harvest potential)	**Guild 2** ("low" harvest potential)
Mallard*	American wigeon
Blue-winged teal	Northern pintail*
Green-winged teal	Canvasback*
Northern shoveler	Scaup*
Gadwall	Redhead

A model (or alternative models) of population dynamics would have to be developed for the species in each guild, although we don't believe all species would necessarily have to be modeled. For example, in Guild 2 we believe pintails, canvasback, and scaup would be sufficient to represent the range of harvest potentials exhibited by all species in Guild 2. For Guild 1, mallards may adequately represent the harvest potentials of the other four species. Coincidentally, we have previous experience in modeling the dynamics of pintails, canvasbacks, scaup, and mallards.

The objective function for each guild would be to maximize the aggregate, long-term cumulative harvest of the modeled species, perhaps constrained by the desire to maintain those species at or

above their NAWMP goals. We envision that the NAWMP constraint would be applied as is currently done with midcontinent mallards. In this case, however, for each guild we would multiply the expected aggregate harvest by the product of the species-specific harvest utilities to determine the regulation-specific harvest value.

A single set of regulatory alternatives could be used for both guilds so that at least on some occasions the regulations for the two guilds would be identical. In those years in which the regulatory choice was different for the two guilds, we expect that the seasons for the two guilds would be run as concurrently as possible so as to minimize the time in which identification of species in flight is necessary.

It would be necessary to spatially stratify each guild optimization process to pursue the goal of Flyway-based management. For example, the spatial structure of Guild 1 probably would follow that of Alternative A, in which three breeding stocks of mallards and three harvest areas were defined. For Guild 2, spatial stratification might only be necessary upon inclusion of key species which did not breed in the midcontinent region and/or wintered in only some Flyways (e.g., black ducks).

Alternative B is intended to be a comprehensive approach to species management, where decisions about the harvest potential of various species are made *a priori*. In contrast to Alternative A, there would be no independent seasons (including species-specific season closures) for any individual species (i.e., all species eventually must be assigned to one of the two guilds). Guild assignments could be changed periodically, but there would need to be established criteria for doing so.

Alternative C

Both Alternative A and Alternative B depend to some extent on the ability of hunters to identify duck species, an ability that has sometimes been called into question (Nieman et al.1987, Wilson and Rohwer 1995, Smith and Dubovsky 1998). An inability to identify ducks in the hand may have been a contributing factor to the apparent ineffectiveness of stock-specific hunting regulations (Rexstad et al. 1991, Johnson and Moore 1996). In recognition of this problem, we thought it appropriate to present what we refer to as the "least-common-denominator" (LCD) approach. This approach involves a focus on a duck species which is deemed to have relatively low harvest potential. The designation of the LCD species might be Flyway-specific (e.g., black ducks in the Atlantic Flyway), and the management objective would be to maximize long-term cumulative harvest of that species. However, all duck species would be exposed to the same regulations; there would be no independent seasons for other species. This alternative provides the simplest regulations conceivable, while maximizing species protection. A large segment of the hunting public (47%) has indicated that simplifying regulations would increase their hunting satisfaction (Ringelman 1997). This approach also probably all but eliminates the potential for species-specific season closures.

Comparison of Alternatives

The following table compares some of the key features of the three alternatives.

Feature	Alternative A	Alternative B	Alternative C
focus	mallard	species' guilds	"least-common denominator (LCD)"
management goals	maximizing mallard harvest, while avoiding seasons that result in other species below population goals	maximizing sustainable duck harvest (in the aggregate)	maximizing LCD harvest, and (implicitly) minimizing the risk of adverse impact to other species
duck harvest potential	intermediate	highest	lowest
# of independent hunting seasons	one to many	two	one
potential for species-specific season closures	higher	lower	extremely low
regulatory complexity (# of stock-specific regulations)	potentially high and temporally variable	moderate and temporally constant	lowest
difficulty in developing population models	intermediate	highest	lowest

Concluding Remarks

Variation in harvest potential among duck stocks means that the dual management goals of minimizing the potential for over-exploitation and maximizing hunting opportunity can be accomplished only to the extent that regulations are effective at directing harvest pressure among stocks in the appropriate manner. This in turn depends on an understanding of the patterns of variation in duck harvest potential, and on the willingness and ability of hunters to comply with stock-specific regulations. In those cases where stocks with different harvest potentials are exposed to a common set of regulations, we must be able to discern the effect of those regulations on the less productive stock(s), and ensure that any constraint on hunter opportunity (via a devaluation of harvest) is sufficient to prevent long-term resource depletion. Unfortunately, the capability of extant monitoring and assessment programs to predict and discern regulatory impacts is limited, and many stock-specific regulations may be ineffective. It thus seems appropriate to conclude by repeating the plea by Babcock and Sparrowe (1989) to balance expectations with reality.

Literature Cited

Babcock, K. M., and R. D. Sparrowe. 1989. Balancing expectations with reality in duck harvest management. Transactions of the North American Wildlife and Natural Resources Conference 54:594-599.

Bailey, R. O. 1981. A theoretical approach to problems in waterfowl management. Transactions of the North American Wildlife and Natural Resources Conference 46:58-71.

Johnson, F. A., and C. T. Moore. 1996. Harvesting multiple stocks of ducks. Journal of Wildlife Management 60:551-559.

Johnson, F. A., and B. K. Williams. 1999. Protocol and practice in the adaptive management of waterfowl harvests. Conservation Ecology 3(1): 8. [online] URL: http://www.consecol.org/vol3/iss1/art8.

Krementz, D. G., R. J. Barker, and J. D. Nichols. 1997. Sources of variation in waterfowl survival rates. The Auk 114:93-102.

Levin, S. 1992. The problem of pattern and scale in ecology. Ecology 73:1943-1967.

Nichols, J. D., and F. A. Johnson. 1989. Evaluation and experimentation with duck management strategies. Transactions of the North American Wildlife and Natural Resources Conference 54:566-593.

Nieman, D . J., G. S. Hochbaum, F. D. Caswell, and B. C. Turner. 1987. Monitoring hunter performance in Prairie Canada. Transactions of the North American Wildlife and Natural Resources Conference 52:233-245.

Patterson, J. H. 1979. Can ducks be managed by regulation? Experiences in Canada. Transactions of the North American Wildlife and Natural Resources Conference 44:130-139.

Rexstad, E. A., D. R. Anderson, and K. P. Burnham. 1991. Lack of sex-selectivity in harvest of mallards under the point system. Journal of Wildlife Management 55:586-592.

Ringelman, J. K. 1997. Effects of regulations and duck abundance on duck hunter participation and satisfaction. Transactions of the North American Wildlife and Natural Resources Conference 62:361-376.

Smith, G. W., and J. A. Dubovsky. 1998. The point system and duck-harvest management. Wildlife Society Bulletin 26:333-341.

Sparrowe, R. D. 1990. Developing harvest regulations strategies for wood ducks. Pages 373-375 *in* Fredrickson, L. H., G. V. Burger, S. P. Havera, D. A. Graber, R. E. Kirby, and T. S. Taylor, eds., Proc. 1988 North American Wood Duck Symposium, St. Louis, Missouri.

Sparrowe, R. D., and J. H. Patterson. 1987. Conclusions and recommendations from studies under stabilized duck hunting regulations: Management implications and future directions. Transactions of the North American Wildlife and Natural Resources Conference 52:320-326.

U.S. Fish and Wildlife Service. 1988. Final supplemental environmental impact statement: issuance of annual regulations permitting the sport hunting of migratory birds. U.S. Department of the Interior, Washington, D.C. 340pp.

Wilson, B. C., and F. C. Rohwer. 1995. In-hand duck identification by hunters at Mississippi Flyway public hunting areas. Wildlife Society Bulletin 23:472-480.

Appendix A -Conceptual Framework

Variation is a defining feature of ecological systems. Virtually all ecological systems exhibit a broad range of variation on temporal, spatial, and organizational scales, ultimately as a function of how individual organisms respond to their environment (Levin 1992). The scales at which individuals are aggregated for management purposes is a discretionary decision, but one that can strongly influence both the benefits and costs of management (Johnson and Williams 1999). Management systems that account for important sources of ecological variation are expected to yield the highest benefits, but also are likely to be characterized by relatively high monitoring and assessment costs (Babcock and Sparrowe 1989, Sparrowe 1990).

Throughout the history of duck-harvest management, there has been a persistent effort to account for increasingly more sources of variation in harvest potential. This tendency was justified, at least to some degree, by a gradual accumulation of information that allowed managers to identify sources of variation at progressively finer scales. However, there is reason to question the efficacy of continuing this trend indefinitely (Sparrowe and Patterson 1987, Johnson and Williams 1999). As the spatial, temporal, and organizational scales at which harvest management is delivered become progressively finer, the marginal gain in management benefit is likely to shrink (i.e., a point of diminishing return) (Fig. A1). At the same time, it is likely that management costs would continue to increase. Therefore, beyond some point, net management benefits are expected to decline. The challenge now confronting duck-harvest managers is to decide what level of management resolution is appropriate given modern data-collection programs, acceptable regulatory mechanisms, the desires of hunters, legal mandates for species conservation, and the magnitude of spatial, temporal, and organizational variability in duck harvest potential.

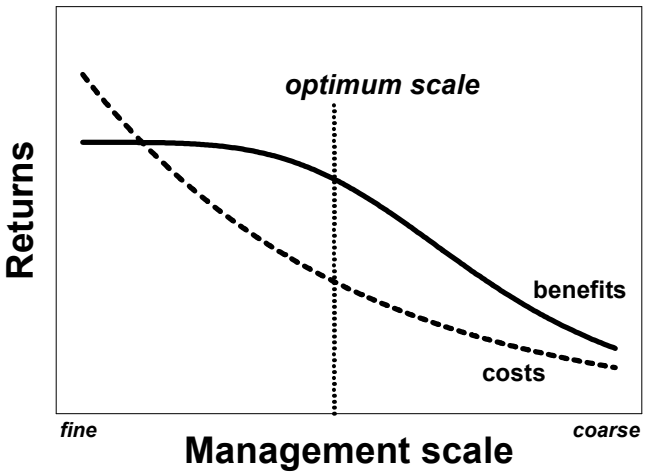

Fig. A1. Theoretical returns as natural resource management is delivered on a range of temporal, spatial, and organizational scales. The optimum management scale produces the greatest net benefit.

To provide a conceptual framework for the problem of scale in AHM, we borrow from fisheries-management jargon and define "stock" as any aggregation of ducks used for harvest-management purposes. Thus, stocks may be defined as spatially segregated breeding-populations of conspecifics, as species, as groups of species, or as any other aggregation that has explicit spatial or organizational bounds. It is not necessary for a stock to exhibit homogeneous demographics and population processes (indeed, any stock will exhibit some degree of heterogeneity). Given this definition of

stock, the problem of harvesting multiple duck stocks exhibits the following key features:

(1) stocks vary in their potential to support sport harvest;
(2) multiple stocks often are exposed to a common hunting season, although stock-specific harvests can be regulated within limits by stratifying hunting regulations on spatial, temporal, and organizational scales (e.g., species-specific bag limits);
(3) stock-specific harvest returns and population trajectories are subject to considerable uncertainty, whose sources include uncontrolled environmental variation, random effects of regulations (i.e., partial controllability), uncertainties in population dynamics, and errors and biases in data-collection programs (i.e., partial observability); and
(4) management objectives are complex, in that they must account for stock-specific values (i.e., not all stocks will be equally valued by hunters), for the legal mandate to prevent over-exploitation of any stock, and for the fact that the distribution of harvest may be as important as its magnitude.

The harvest potential of any given stock also is likely to vary among years due to variation in habitat conditions. Stocks that exhibit a high degree of annual variation in harvest potential are best harvested under a regime that allows annual changes in regulations. On the other hand, stocks exposed to relatively stable habitat conditions can be harvested effectively with regulations that are promulgated for multi-year periods.

In defining the scales of duck-harvest management, it may be helpful to think about levels of "stratification" in both stocks and in hunting regulations. As in statistical inference, the purpose of stratification is to increase efficiency by dividing heterogeneous units into smaller, more homogeneous ones. In a harvest-management context, a high level of stratification involves the delineation of many, relatively homogeneous duck populations. It also refers to regulations that vary on fine spatial, temporal, and organizational scales and, thus, to those designed to exploit differences in harvest potential among stocks. As mentioned previously, a high level of stratification (or alternatively, a fine resolution or scale of management) is expected to produce the highest harvest benefits, but also is accompanied by the highest costs (Fig. A2). Conversely, a low level of stratification in populations and regulations leads to the lowest benefits and costs.

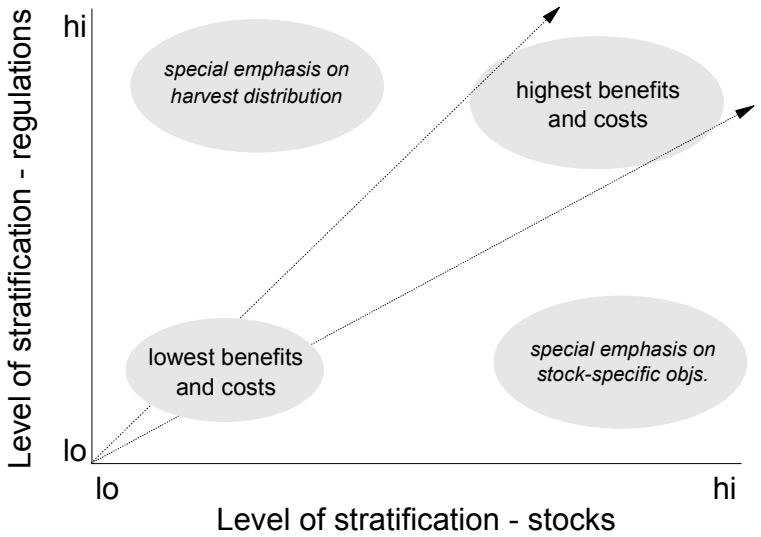

Fig. A2. The relationship between stratification of stocks and hunting reglations. The arrows represent proper balance between the two. The upper left and lower right quadrants represent exceptions based on particular management goals.

In deciding an appropriate level of stratification, it is important to recognize the relationship between the level of stratification of stocks and that of hunting regulations. Regulations that are highly stratified on spatial, temporal, or organizational scales are not particularly advantageous if the number of identified stocks is small. An important exception to this rule, however, involves the case where the harvest-distribution goals cannot be met passively, and so require regulations that are highly stratified. In this case, however, coarsely stratified stocks will increase the chance of negative biological impacts on the less productive segments of those stocks. These adverse impacts can be prevented by the delineation of more stocks, but there could be difficulties in addressing harvest-distribution goals if this is accompanied by a low level of stratification in regulations. The challenge to managers, then, is to determine the intermediate level of stratification in stocks and regulations that represents an acceptable balance among competing considerations.

The following example may be helpful in demonstrating these concepts. Suppose that we have two species, like mallards and canvasbacks, that vary in their potential to support harvest. A course-grain approach to management would treat the two species as a single, aggregate stock subject to a common hunting season (Fig. A3[A]). However, if harvest potential varies greatly between the two

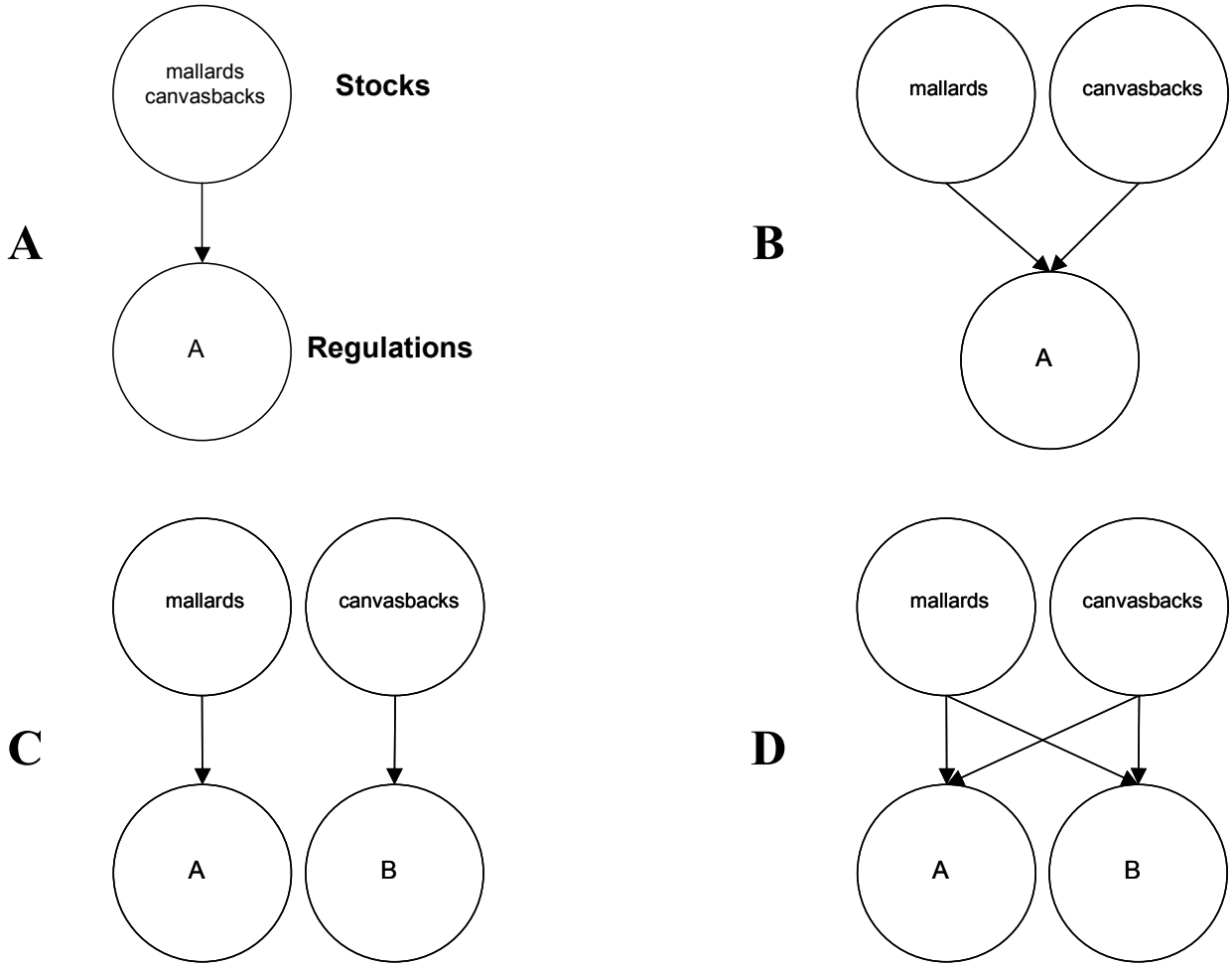

Fig. A3. Possible approaches to stratifying stocks of birds with different harvest potentials. See text for a description of the different approaches.

species, then an objective to maximize long-term cumulative duck harvest may sacrifice viability of the less productive species for harvest of the more productive one. An alternative would be to divide (stratify) the single stock into two, represented by the two species (Fig. A3[B]). Now the dynamics of the two species could be tracked separately and the harvest-management objective could be modified to help ensure persistence of the less productive species. However, the two species would still be subject to a common set of regulations. If hunters can distinguish between the two species on the wing, or if the two species winter in different regions, regulations could be stratified so as to allow regulations that are species- or area-specific (Fig. A3C), and two independent optimizations of harvest strategies would be possible. This approach is currently in use with midcontinent and eastern mallards. Unfortunately, identification of birds on the wing is difficult in many cases and wintering areas are rarely disjunct (Fig. A3D). Accounting for these problems requires a joint consideration of the species- or area-specific decisions because they are not independent in their effects. Moreover, there is no unique regulatory strategy that will maximize harvests of the two stocks, because the maximum allowable harvest could be allocated (distributed) in many different ways. Thus, this situation requires a consideration of the most desirable harvest distribution, which then must be expressed explicitly as a management objective.

Appendix A - Abridged Comments On This Document From The AHM Working Group

General Comments

• What does (should?) the "multi" in "multi-species management" mean? Does/should it mean "more" (as in more than just mallards) or "all"? The answer to that question could help narrow (?) the range of options. For what it's worth, I'm not all that worried about the 9 other principal species breeding in the midcontinent region, because the BPOP survey lets us keep pretty good track of their status. The species that I have nagging fears about are the ones that we have so little hard data on that we aren't even considering adding them to the mix. What will multi-species management do for them?

• The paper stresses that the options presented are not the only ones available, and it's clear that there are other possible approaches - such as different regulatory approaches within flyways, or a point system. Part of this process should involve encouraging/facilitating the flyways and other constituent groups to do some creative thinking, and maybe even consider approaches with which we have little or no prior experience. I imagine you are cringing right now, since many potential approaches would be difficult to technically evaluate. However, as the paper notes, this issue entails a balance between developing an approach that is well-supported by biological information and one that satisfies social and political concerns (perceived and actual). We have recent experience with attempts to satisfy value judgments using an approach that provided little opportunity for prior biological evaluation (i.e., the "f-word" extensions), but we (you) developed ways to handle the added uncertainty.

• I agree with -----'s thought that we need to seriously consider if managing multiple species in a combined AHM approach is the best way to tackle the problem of multi-species management. This will be a very resource intensive project, and I think we need to consider if the effort is necessary or will provide results that are far superior to the current approach. Do we need something this complicated to do what we want to do? The goals outlined on page 2 (optimize long term-harvest while not over- or under-harvesting any species, and enhance Flyway based management) do not necessitate a multiple stock approach. Should we include an option to leave things as they are, while perhaps refining some of the existing models (both mallard & non-mallard models)? Or, as others have suggested, include completely different alternatives to multi-stock AHM?

• When considering the relative cost-benefit of a multiple stock AHM approach versus the current approach, I think we also need to consider all of the subjective decisions that will need to be made to build any of these models (or, for that matter, have been made in our current system). For example, in Alternative A, how can one objectively determine the shapes of the harvest devaluation curves in Figure 2? What species merit special concern and independent seasons? What stocks get modeled? In Alternative B, how are species assigned to guilds? Which species are used in modeling efforts? It seems to me that in any system, whether based on models or expert opinion, plenty of judgment calls & subjective decisions have to be made. I wasn't around in the pre-AHM days, so I can't appreciate all of the improvements it has brought, but I thought that one of the selling points of the AHM system over the old "smoke-filled room" system was objectivity. Should we still claim that as a merit of AHM, especially as it increases in complexity? But maybe the types of subjective

decisions we make in AHM are preferable to those made in pre-AHM days, because they aren't based on the outcome. So this, in some sense, can be considered a more objective system.

• I think we may need to be a little more creative in how we structure seasons, perhaps with differential bags/season lengths within a flyway (but no point system - too much baggage). I think that in order to address harvest distribution issues repeatedly broached by the flyways, we may have to see if doing so would alleviate some of the concerns (we still would have to address the among-flyway harvest-distribution issues). By not addressing these issues over the last several years, we've gotten further away from what I think we all envisioned AHM should be -- less contentious and more predictable. If we don't try something new, I fear the situation will only get worse. I know that coming up with predicted harvest rates for the scenario above would be difficult and perhaps not as accurate as we'd like, at least initially. But, as ----- said, we came up with something for framework dates, so.... However, I feel it important that if we do go forward with such an idea, that at least the following 2 conditions would have to be met by the flyways: (1) no options allowed; each state would get to a fixed bag limit and season length, but not an option for either a larger bag/shorter season or smaller bag/longer season, and (2) absolutely NO changes to the packages until we have gained sufficient experience with them to get what we feel are reasonably precise estimates of harvest rates. We'd probably really be out on a limb with our estimates in such a scenario, which should make all of us a little nervous.

• The Atlantic Flyway might be best served, and duck harvests better managed, by breaking out a north and south region with different frameworks allowed in each. I think the south could then follow the same prescription as the Mississippi Flyway and feel more comfortable with the decision critieria.

• ----- suggests that the southern portion of the AF might be comfortable following the same prescription as the MF. Just for the record, I'm not convinced that's the case. I think they (we) may be amenable to some influence of midcontinent stocks in our regulations, but I'm not sure the southern states want to be considered solely midcontinent, given the substantial proportion of eastern stocks in our harvest. Also, while I agree the that AF would be best served with increased spatial stratification in regulations (splitting into a N & S region), I am also sensitive to the argument about the increased costs of a finer spatial scale of management.

• I agree with ----- that we should consider having different packages within flyways. I have never understood why this couldn't work, except that it would require a great deal of time to hammer them out. Also, while I have never been a strong proponent of the point system, I can definitely see benefits to it for multi-stock management. I know that days are considered the major regulator of duck harvest, but bag limits do have their place. Isn't that why we have restrictive limits on wood ducks, redheads, scaup, pintails, etc.? As we get more into multi-stock management, bag limits will continue to be used to restrict harvest of some species (I don't think we will reduce season length to 2 days so we can have a 5 duck limit that includes cans and pintails). As additional species restrictions come into play, the regs seem to get very messy. I think a point system approach may be cleaner and more acceptable - even if there is some slop due to reordering - there is plenty of slop with one bird and closed season bag limits.

• In general, I, personally, am an advocate of simplicity in regulations, and I believe that the waterfowl regulations currently in place are too complex. In particular, regulations that require hunters to identify birds on the wing (season closures and, to some extent, species-specific bag limits) are something that we should move away from, if possible. I realize that in doing so there are tradeoffs in terms of harvest opportunity, and I'm not sure how far I'd go in compromising opportunity for simplicity.

• I was surprised to see that the objective function was aggregate, long-term cumulative harvest. My impression was that we were going to consider other objective functions as well. Is that something that will wait until Dave Case & Dale Humburg finish their work on the topic?

• We may have to pay more attention to the harvest distribution of species other than mallards. Not all flyways have equal potential to harvest some species, and I would think the flyways would want that to be a consideration in the strategy. I realize that we don't have a lot of data to address this the way we'd like to (i.e., derivation of birds for each flyway), but perhaps we could look at long-term trends from harvest surveys to give us some feel for how each Flyway may impact the species? It may be that this issue comes to play only in development of the regulatory alternatives, and the details of how to handle it could be saved for later. Nonetheless, we may want to surface this possibility now, if we think there is any hope (or need) for addressing it.

• We likely will be stating some sort of population level for each species as an objective, regardless of the strategy developed. We've used the NAWMP goal (with a modification to account for mallards in the Lake States) for midcontinent mallards in the past, and it sounds like we may be using them in the future. Although not upon us yet, the NAWMP is going to try to move toward 'scalable' goals, which would also have an impact on AHM (although it may be primarily a communications issue). Also, they may begin to state goals for segments of species (e.g., eastern and western wood ducks). My only point here is that NAWMP goals may not be fixed at a given value for each species over time the as they have in the past, and the way we've used them in AHM in the past may not be possible.

• It seems like the status of "other species" will only impact the objective function, at least in Alternative A and perhaps also in Alternative C. Does that mean the mallard model set, the associated hypotheses, and the model weight updating procedures will essentially stay the same? If that's not the case, then I'm having a hard time envisioning a model set for any one of these alternatives that would keep the "adaptive" in AHM. Could multi-species models continue to test compensation vs. additivity and weak vs. strong density-dependence? If not, what hypotheses will be tested, and how? Alternative B will require more than just switching to 2 objective functions, and the logistics of that (model sets, hypotheses, predictions) are too much for me to fathom. Is it doable?

• Involving hunters in this process would be very beneficial. It seems we always say this would be nice to do, but it never gets done on a large scale. Maybe the flyways and individual states should look into repeating Ringelman's duck hunter survey, but this time focus it more on some of these key questions related to multiple-species AHM approaches (e.g., how do feel about having 2 separate

duck seasons, which often would not run concurrently?). Or, if we could identify just a few critical human dimensions questions, could these be added to the federal waterfowl harvest survey for a year or 2?

• I also support the idea of getting hunter input into the process, although I'm not sure we yet have a way of effectively getting the information that would be useful to us. Depending on the degree of complexity in regulations we ultimately feel may be possible, we also may want to bring in LE to get their opinion. I realize that we shouldn't be formulating our regulatory alternatives largely on concerns as to how well they can be enforced. However, I think we at least should get a read by LE regarding how complex the regulations could be and still have a good success rate in our prosecutions of violations. I don't think we should be promulgating regulations in which we won't be able to effectively adjudicate.

• I wonder if, before embarking on any particular approach to multiple-stock AHM, there might be opportunity for some directed, true experiments with regulations for some species of concern. In some cases, the political hurdles might be less imposing, because many of the species we're concerned about are more spatially or temporally restricted in their importance in the harvest than malards. For example, it might be possible to convince the Atlantic Flyway to spend a few years experimenting (with treatment and control states) with black duck regs, or a few key harvest states to experiment with alternative pintail regs, while remaining states/flyways continue to use current ad hoc regulations. The key point to communicate would be that these would be TEMPORARY experiments, aimed at quickly gathering baseline information on the effects of novel regs, that would then be used to drive regulatory approaches at more traditional scales (annual, flyway-specific regs).

• In this concept paper, and in most discussions about changes to AHM, an explicit or implicit constraint is given that whatever we do, it has to be able to be supported with existing monitoring programs. I know it isn't realistic to expect lots of new resources for additional monitoring of ducks, hunters, etc., but at this early stage of developing alternatives I don't think we should be overly tied to this constraint. At a minimum, we should carefully document the variables associated with each alternative approach that need to be monitored in order to make the approach adaptive. Then we can see whether and how much we need to re-align or expand existing monitoring programs.

Alternative A

• I think the potential for having species-specific season is valuable. Because we don't have a very good grasp of the dynamics for some species, this alternative would allow us to target an individual group should the status of that group become unacceptable (either biologically or politically). However, as you note, exceptions for inclusion of species in the 'other ducks' group will be possible and almost certainly will be lobbied (either for more protection of the group or for additional hunting opportunities). I see this as a potential pitfall for this alternative, and it seems similar to our current approach of trying to shoehorn some of these other species into the current AHM framework. As the number of these special cases proliferate, regulations tend to become much more complex. Also, databases for most of these species are quite limited, and I question whether the amount of staff time required to develop strategies for these other species is the best use of that time. And the time

commitment doesn't end once the strategy is 'finalized'; much effort has been spent on the canvasback strategy over the past couple of years trying to 'tweak' the strategy a bit to get a more palatable result. I think of the staff time that has gone into canvasback, pintail, and scaup harvest strategies/recommendations, and wonder if such an approach could even be supported if more 'special cases' are proposed, given resource limitations. The number of exceptions could be limited if there was overwhelming support to make such exceptions extremely rare, but AHM has not fared well (in my opinion) at limiting changes to the AHM process to date (it seems as though some change in the alternatives has occurred almost every year since the inception of AHM).

• Focus on mallards and the nine other "principal species" sounds nice, but if wood ducks aren't included in this alternative then it is seriously flawed - especially for the 2 eastern flyways. Not incorporating a species that comprises 22% of the duck harvest in the AF and 9% in the MF (2001 estimates) is unacceptable to me. We all know the reasons for this situation (some all too well), but we can't ignore it. The document perhaps should highlight the importance of finishing work on wood duck modeling ASAP and incorporating it into the AHM process somehow. As I understand it, the NAWMP update is NOT going to include population goals for wood ducks, even though they have included estimates for eastern and western population levels. I agree with ----- that a species' contribution to total duck harvest (and a flyway's ability to influence harvest of a species) should be considered in addition to how their status relates to their NAWMP goal. A species such as shoveler (about 4.5 % of harvest in MF and CF) shouldn't have equal weight as a species that comprises a higher percent of the harvest - such as green-winged teal (10 % of harvest in MF and CF) or wood ducks (if incorporated).

• I would suggest that the optimal package for each flyway depend in part on composition of the harvest as well as species status or their ability to sustain harvest. This might be a modification of Alternative A, where the number of species above NAWMP goals is not simply counted, but is weighted in some way to reflect harvest pressure or importance. Ideally, this also would not be limited to mid-continent BPOPs; if it included wood ducks and black ducks, it might actually be useful to the Atlatnic Flyway! As proposed, Alternative A puts too much emphasis back on mid-continent duck stocks that account for a much smaller % of total duck harvest in the AF, especially in the Northeast.

Alternative B

• Alternative B has a lot of appeal for me, and I honestly thought this approach would have to be the one AHM eventually would gravitate toward because we simply can't deal with all species individually. However, you point out a couple of issues that are troublesome. First, the ability to model the dynamics of a group of species quite possibly will be much harder than developing one for a single species. Also, our monitoring for some if these species may be suspect at times (e.g., BWT possibly redistributing themselves in response to water conditions as they appeared to do in 1994, pintails perhaps moving outside of survey areas in dry years). Depending on the state variables used to develop the optimal strategy each year, those instances might have a large effect on the outcome. Also, the fact that this alternative does not have a provision to deal with an individual species (or stock) that may require additional management efforts is troublesome to me. My concern

would be more for a group that needs additional protection, but other may argue that a group could withstand additional pressure. Both are reasonable. Finally, I have just a couple of questions -- you don't need to answer them now, but a couple of issues weren't clear to me in the paper. First, a group moving from one guild to another is possible. As you state, we would need to come up with some criteria to allow such a change, and I agree. But when a species goes from one guild to the other, would additional modeling for both guilds (in your example) be needed to account for the change, or would the models for the 2 guilds be sufficiently general so you could swap the species without ramifications to the process? Second, do you envision differences in bag limits for species within a guild as being part of the regulatory alternatives, or would 1 bag limit be imposed for all species within a guild and the only difference in regulations be in season length?

•I don't have any major concerns about the technical workings of this approach, although I don't think that there should be the opportunity to change guild assignments. One thing I am wondering about is how the species are assigned to a guild. In particular, grouping pintails with canvasbacks seems counter-intuitive to me. When I think of guilds I think more of life-history characteristics and I believe more emphasis should be placed on those rather than factors such as NAWMP goals, long-term trends (BPOP graphs for pintail and cans are much different), and harvest age ratios - which may be artifacts of human-induced changes in the environment. An important reason pintails are not doing well is the result of agricultural impacts. However, I think of them more as an r-selected species, whereas I think of canvasbacks as being more K-selected. Pintails could probably withstand much more harvest pressure if we could change land use practices in the grasslands (and get some rain in Alberta), whereas I'm not sure that the same could be said for canvasbacks - they will continue to plod along and bounce around their long-term average. I realize that the current situation is that pintails probably can't withstand more harvest pressure and neither can canvasbacks - and that is why the proposed approach places them in the same guild. But they are in the same "low harvest potential" guild for different reasons (pintails are suffering from ag impacts and cans are just being cans)- and for practical purposes that may be OK. But, what if Canada implements a huge CRP-type program (and we get some rain in Alberta) and pintails start to rebound quickly? I realize that the proposed alternative builds in the possibility of changing guild assignments but as I said I don't like that approach. I would rather see more of a life history-based approach that would place pintails in guild 1 with other upland-nesting, "r-selected species". Inclusion of a pintail model along with the mallard model for this guild would act to make the strategy more conservative but I think that might be desirable because the land use practices that affect pintails to a high degree, also impact other upland nesting species but to a lesser degree because they initiate nests a little later in the season (and may be less likely to have their nests plowed under).

• I really like the temporal constancy in regulatory complexity, the lower potential for species-specific closures, the high harvest potential, and the fact that the focus is on species' guilds. The focus on species guilds, rather than mallards, might be more palatable to some because it will explicitly take into account the status of the other species on the "front end." In your table showing the comparison of alternatives, you say that this alternative has lower potential for species-specific season closures. While that's true, if I understand it correctly, this alternative would establish two duck seasons, so there would be a partially closed season for all the species in the guild that has the shorter season that year. So there would be partial season closures for all species in Guild 2 in every

year that the prescribed season length for Guild 2 was shorter than that prescribed for Guild 1. In the two guilds you've proposed, gadwall and wigeon are in different guilds. This is an example that I think would be unworkable: for part of the overall duck season, the season could be open for gadwall and closed for wigeon. These two species are often found in mixed flocks, and suggesting to hunters that we expect them to consistently discriminate between these species on the wing or risk violating is a bad idea in my opinion. Would it be possible to do joint optimization with the two guilds? Or maybe an LCD approach with Guild 2, setting the season according to the status of Guild 2 rather than focusing on one species deemed to have the lowest harvest potential (actually, I guess this may not be too different, in practice, than Alternative C)? If we went with something like Alternative B, I think the AF would require that Guild 2 initially include black ducks and possibly wood ducks and incorporate spatial stratification.

Alternative C

• Your description suggests that there would be no species-specific bag limits with this alternative. For example, if the LCD species were black ducks, and the prescribed regulation were a 30-day season with a 1-bird bag, would we be stuck with a 1-bird bag limit in the aggregate? Although I like the overall simplicity of this alternative, I think it's gone too far in terms of compromising opportunity and represents an extreme that likely would be unacceptable.

• Can Alternative C be reworked to make it a reasonable alternative? As it stands now, I don't think that anyone would find it acceptable.

• I agree with others that this alternative foregoes too much harvest opportunity on some species for the sake of protecting the status of LCD species.

• Alternative C would definitely simplify regulations, but I don't feel it would be viable. Too much harvest opportunity would likely be foregone, limiting support for it. I agree with -----, however, that it should be listed, because it identifies the trade-offs one would need to consider to obtain very simple regulations.