Report from the Joint Task Group for Clarifying North American Waterfowl Management Plan Population Objectives and their Use in Harvest Management

MICHAEL G. ANDERSON, Institute for Wetland and Waterfowl Research, Ducks Unlimited Canada, Stonewall, MB R0C 2Z0, Canada
DALE CASWELL - Canadian Wildlife Service, Waterfowl Management Division,, 123 Main St., Suite 150, Winnipeg, MB R3C 4W2, Canada
JOHN M. EADIE - Department of Wildlife, Fish & Conservation Biology University of California, Davis CA 95616, USA
JEFFREY T. HERBERT - Montana Fish, Wildlife and Parks, P.O. Box 20070, Helena, MT 59620, USA
MIN HUANG - Connecticut Department of Environmental Protection, 79 Elm Street, Hartford CT, 06106, USA
DALE D. HUMBURG - Missouri Department of Conservation, 1110 S. College Ave., Columbia, MO 65201 USA
FRED A. JOHNSON, United States Fish and Wildlife Service, Division of Migratory Bird Management, Gainesville, FL 32653, USA
MARK D. KONEFF, United States Fish and Wildlife Service, Division of Migratory Bird Management, Laurel, MD 20708, USA
SETH E. MOTT, United States Fish and Wildlife Service, Division of Bird Habitat Conservation, Arlington, VA 22203, USA
THOMAS D. NUDDS, Department of Integrative Biology, University of Guelph, Guelph, ON N1G 2W1, Canada.
ERIC T. REED, Canadian Wildlife Service, Environment Canada, Migratory Birds Conservation Division, Gatineau, PQ K1A 0H3, Canada
JAMES K. RINGELMAN - Ducks Unlimited, Inc. Great Plains Region Office, Bismarck, ND 58501, USA.
MICHAEL C. RUNGE, United States Geological Survey, Patuxent Wildlife Research Center, Laurel, MD 20708, USA
BARRY C. WILSON, - U.S. Fish and Wildlife Service, Gulf Coast Joint Venture, 700 Cajundome Boulevard, Lafayette, LA 70506, USA

Table of Contents

Executive Summary

This report addresses one of the most fundamental debates in waterfowl policy and management -- the relative roles of habitat conservation and harvest regulation. The original framers of the North American Waterfowl Management Plan (Plan) recognized the inherent linkages among harvest, habitat, and hunters. The Plan set the stage for the next two decades of waterfowl conservation, during which managers demonstrated a capacity to deliver habitat initiatives through joint ventures, developed a technical framework for harvest management, and became increasingly aware of the role of stakeholders, especially hunters. To date, however, the waterfowl management community has not explicitly integrated these elements under a cohesive framework. *This integration will require identification of meaningful, measurable goals that integrate habitat conservation, harvest management, and stakeholder support.*

An explicit connection between harvest and habitat management will be required. *Without this linkage, Plan partners lack a shared context for their habitat and population goals, and harvest managers cannot translate Plan accomplishments into harvest opportunity*. The consequences are inefficient allocation of resources to meet Plan objectives, and habitat conservation efforts that may not affect important vital rates for waterfowl.

A unifying framework is based on fundamental concepts of population dynamics that incorporate the effects of harvest and habitat management into a common model. Yield curves simultaneously depict carrying capacity, maximum sustainable harvest, equilibrium population sizes and total harvest over a range of harvest rates. *We believe that yield curves provide the conceptual framework for the integration of harvest and habitat management.*

The original Plan established a benchmark for hunter satisfaction—waterfowl populations that existed in the decade of the 1970s. Underlying the highly variable moisture conditions lies a foundation of habitat—wetland basins, grasslands, natural wetland foods—that represents the potential of the landscape to produce and sustain waterfowl. The Plan founders clearly believed that substantial habitat had been lost between the 1970s and the mid-1980s, and sought to make steady progress in wetland restoration and enhancement to ensure lasting gains in waterfowl carrying capacity. *We are interpreting Plan goals as the desire to expand (or at least maintain) yield curves, which in turn can be interpreted as increasing (or at least maintaining) continental carrying capacity.*

Responsible harvest management and hunter satisfaction are tied to the average harvest rate sought by harvest objectives. Harvest objectives that seek less than the maximum sustainable harvest guard against uncertainty, provide a measure of protection for less productive species managed under a common duck season, allow higher average populations sizes, and require less variable harvest regulations. *We believe harvest management objectives are best described as desired points along the yield curve.*

Plan objectives represent population sizes that realistically could be attained by habitat conservation programs and provide for satisfactory levels of hunting. *We recommend a "shoulder strategy" as a way to integrate habitat and harvest management, as a way to interpret Plan objectives, and as a way to assess continental objectives under both programs.* This strategy allows the use of the annual breeding population index as a direct assessment of Plan success, does not result in lost harvest opportunity in the face of changing habitat conditions, and lays the groundwork for integrating decisions about waterfowl and wetland conservation.

Deliberate policy dialogue will be required to balance tradeoffs within the waterfowl management community. For fixed continental Plan population objectives, the choice of a shoulder point determines both the harvest objective and the desired expansion of the yield curve. A desire for greater harvest opportunity will require increased carrying capacity and thus, a greater investment in habitat improvement. Harvest opportunity will be lower if habitat conservation efforts are ineffective or the management community de-emphasizes objectives for maximum harvest. *The tradeoffs may be too difficult to negotiate unless revision of the Plan population objectives is also considered.* Over the last 20 years, new data and assessment tools suggest that the abundant waterfowl populations of the 1970s were driven in large part by above-average water conditions, and the goal of achieving such populations under average water conditions by improving the base of habitat may be more ambitious than previously thought.

Considerable technical work will be required to integrate uncertainties about habitat and harvest management. Pursuit of a unified framework for waterfowl management at the continental scale must include additional elements, particularly the incorporation of stakeholder desires, clarification of key ecological uncertainties such as the functional form of density dependence, and models that link local habitat management with continental waterfowl demography.

Recommendations from the Joint Task Group are intended to motivate the policy decisions and the technical work necessary to unite all aspects of waterfowl management. Implementation of these recommendations will require communication and coordination among diverse internal and external stakeholders, completion of new technical assessments for habitat and harvest management, the addition of technical capacity in the area of human dimensions, and leadership from agencies with mandated responsibility for waterfowl management. Six primary recommendations include:

- The U.S. Fish and Wildlife Service (FWS) and Canadian Wildlife Service (CWS), in consultation with the Flyway Councils, should adopt a "shoulder strategy" for northern pintails and mid-continent mallards. The principles of coherence and integration should be central components of the revised U.S. federal EIS on waterfowl harvest,
- The Plan Committee should adopt the same "shoulder strategy" to ensure coherence between harvest policy and habitat objectives, and focus the attention of the joint ventures on the conservation actions designed explicitly to enhance

continental carrying capacity (*K*). The principles of coherence and integration should be central components of the 2009 Update of the Plan.

- The federal wildlife services, together with interested partners, must commit to enhancing technical capacity for the Plan's Science Support Team (NSST) and the Adaptive Harvest Management Working Group (AHMWG) as both will have key roles in the technical integration of waterfowl management.
- The waterfowl management community must focus more scientific efforts on reducing the key ecological uncertainties surrounding current models of population dynamics (e.g., density dependence) and the relationships between waterfowl vital rates, carrying capacity (*K*), and landscape properties that habitat managers strive to manipulate.
- The FWS and CWS directorates should convene a waterfowl management policy summit in the near future to address the decisions necessary to develop the policy framework for habitat and harvest management integration.
- A new Human Dimensions Working Group (HDWG) should be convened to refine an assessment of waterfowl stakeholder values and the approach for more explicitly incorporating this information into management decisions.

I. Introduction

Waterfowl management has been a prime example of the American conservation movement. For more than 100 years, hunters, political leaders, and others have participated in one of the most significant conservation efforts in North America. These efforts have been driven by the simple fact that perpetuation of our ability to harvest waterfowl is dependent on sensible hunting regulations and the protection of important waterfowl habitats. In 1986, the North American Waterfowl Management Plan (Plan) recognized *both* that “conservation of habitat is the pressing imperative if waterfowl are to be maintained...” and that “Harvest management is clearly important and government agencies should continue to ensure that regulations and enforcement are sufficient to maintain adequate abundance and diversity of waterfowl populations for all users.” (U.S. Department of the Interior and Environment Canada 1986). Since then, waterfowl managers have developed increasingly elaborate programs and methods for managing harvest, mapping habitat, modeling populations, and generating funds for conservation efforts. Yet today, all these components operate largely in isolation and with little forethought to their impacts on one another.

In the long term, harvest potential depends on the ability of the North American landscape to produce and sustain ducks. Habitats across that landscape are increasingly under siege by a wide number of forces, including intensified agricultural, energy, and water development; expanding human population; and climate change. As a result, the significant habitat conservation achievements of the joint ventures and other Plan partners are being compromised. Twenty years after the Plan was initiated we still have only a rudimentary idea of how habitat accomplishments have measurably affected waterfowl populations. Likewise, we have not explicitly stated the role that harvest management should play in achieving Plan population objectives. Without a well-defined linkage between harvest management and habitat conservation, optimal decisions regarding the waterfowl resource cannot be made. Continuing to operate in this fashion jeopardizes both efforts and could cause us to lose credibility and public support.

Large investments of resources (time, people and money) have been expended on waterfowl harvest management, based on the assumption that harvest management leads to sustainable waterfowl populations. At the same time, considerable uncertainty exists about the extent to which harvest even affects populations of North American waterfowl, relative to other significant drivers of population size, such as habitat and climate change. The question arises, in light of these kinds of key uncertainties, whether it is possible to justify the present levels of expenditure of resources on harvest management versus other activities that arguably affect waterfowl populations to greater extents. Today, more than ever before, society demands transparency and accountability for the decisions made by policy makers and managers in the allocation of limited resources.

Further, we do not fully understand what motivates hunters and other stakeholders despite long-standing acknowledgement of the importance of including human dimensions as part-and-parcel of waterfowl management. We have invested significant resources in habitat conservation and Adaptive Harvest Management (AHM) (Williams and Johnson 1995), but comparatively little has been done (until recently) to determine and address the needs, desires, and concerns of stakeholders – especially waterfowl hunters. Without this kind of information, we can never adequately answer the fundamental questions before us, such as how much harvest or hunting opportunity does it take to satisfy stakeholders, how much habitat is needed to support populations that can sustain that harvest, and how can we best balance desired harvest with achievable habitat conditions? Recently, additional attention has been focused on accountability for Plan expenditures and accomplishments, illustrating that failure to explicitly account for social and political consequences of decision-making can leave management agencies unable to assess societal satisfaction with management outcomes.

<u>The Joint Task Group</u>

Impetus for clarifying the relationship between the Plan and AHM arose from two recent events: (1) the AHM community has undertaken a broad discussion to clarify the role of population objectives in harvest management, and (2) the Plan community is completing its first comprehensive biological assessment. Both of these events underscore the urgency, as well as the opportunity, to scrutinize the objectives of each program and to ensure that they constitute a coherent overall waterfowl management strategy.

The North American Waterfowl Management Plan Committee (Plan Committee) and the International Association of Fish and Wildlife Agencies (IAFWA) Adaptive Harvest Management (AHM) Task Force in 2005 sanctioned the appointment of a Joint Task Group (JTG), consisting of scientists and managers drawn from both management communities to explore options and recommend preferred solutions to reconciling the use of Plan population objectives for harvest and habitat management. The JTG reviewed and analyzed existing information concerning environmental and harvest dynamics of ducks derived from AHM and other research to:

- clarify the biological meaning of Plan population objectives and the implications for monitoring and assessment;
- develop options for incorporating those objectives into AHM and describe the implications of those options for both harvest and habitat management;
- engage all stakeholders in consultations to identify a preferred option for adoption and implementation.

The JTG believes that the waterfowl management community faces an impending crisis. Without a comprehensive approach to waterfowl management planning, conflicts between harvest and habitat management goals and strategies may erode support for both programs. We must establish meaningful, measurable goals that integrate these components and that provide a unifying framework for future waterfowl conservation efforts. The JTG reached the conclusion that a re-visioning of the Plan by 2009 to explicitly link harvest, habitat, and humans with the same bold, forward-thinking that brought the Plan into existence 20 years ago will reduce the risk of future loss of harvest potential and the myriad of societal benefits associated with waterfowl habitats. The remainder of this report provides our reasoning for this finding and provides recommendations for moving forward to incrementally build a framework that unifies not just habitat and harvest management, but the human dimensions component as well.

II. A Unifying Framework for Waterfowl Management

The Role of Harvest in Determining Waterfowl Population Size

The harvest of renewable natural resources is predicated on the theory of density-dependent population growth (Hilborn et al. 1995). This theory predicts a negative relationship between the rate of population growth and population density (i.e., number of individuals per unit of limiting resource) due to intra-specific competition for resources. Density dependence must operate at some level in waterfowl populations, perhaps through a variety of mechanisms operating at different spatial and temporal scales. But empirical evidence for density-dependence in waterfowl has been elusive, probably in part because of the adaptability of waterfowl and their ability to move among habitats when resources become limiting. At a continental scale, however, there is at least circumstantial evidence for density-dependent recruitment in several duck species. For example, there is a negative relationship between the fall age ratio (young/adult) and the size of the mid-continent mallard breeding population (Fig. 2.1).

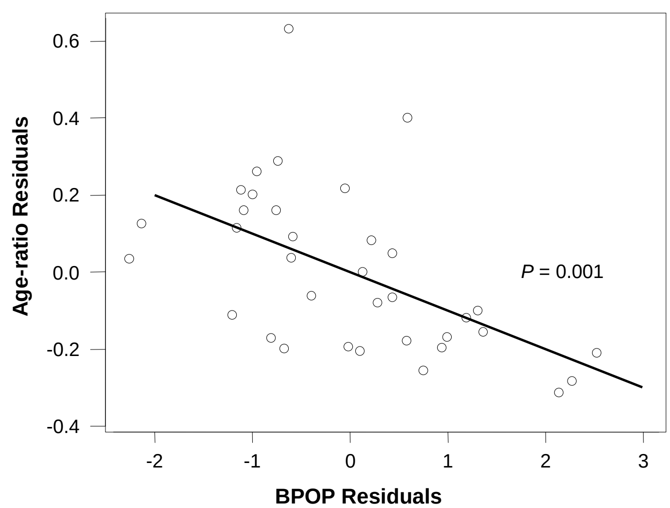

Figure 2.1. The relationship between fall age-ratios and breeding-population size (BPOP) of mid-continent mallards, after accounting for the effect of variation in May ponds in Canada.

The logistic growth curve depicts a trajectory for a population regulated by density dependence (Fig. 2.2). As the population grows, it approaches and stabilizes at *K*, the population size that can be supported by the available habitat in the absence of harvest. When a population closed to immigration and emigration reaches *K*, recruitment equals mortality.

According to the logistic model, populations respond to harvest through increased reproductive output or decreased natural mortality because more resources are available per individual. Harvest managers seek an equilibrium population size in the presence of harvest, at which the harvest, if not too heavy, can be sustained without destroying the breeding stock. The relationship between equilibrium population size and harvest is referred to as a "yield curve" (Fig 2.3). A yield curve depicts how the size of the population and the sustainable harvest change as harvest rate is increased from 0 (on the right of the graph) to the maximum renewal capacity of the population (on the left of the graph).

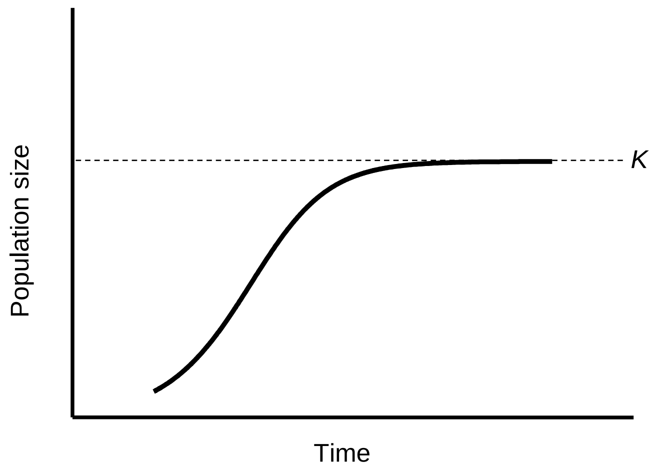

Figure 2.2. A logistic curve depicting the growth of a population regulated by density-dependent factors.

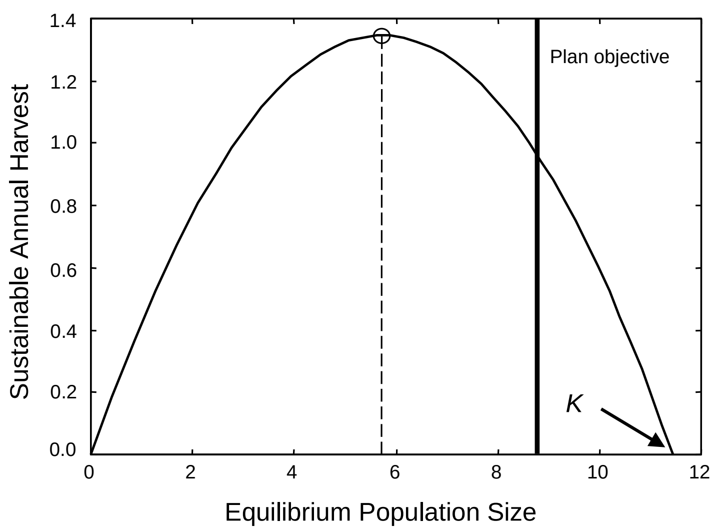

Figure 2.3. Sustainable annual harvest as a function of equilibrium population size (in millions of ducks) for mid-continent mallards (including WI, MI, and MN). This model suggests a carrying capacity (*K*), under the average number of Canadian ponds of 11.5 million ducks, and a maximum sustainable harvest when the breeding population size averages 5.9 million ducks. The Plan objective for mid-continent mallards, including the three Great Lakes states, is 8.8 million.

To demonstrate these concepts, we rely on information about mid-continent mallards derived from the AHM program, but emphasize that mallards merely serve as an example. Although the strength and form of density dependence undoubtedly vary among species, the basic concepts of habitat limitation and sustainable harvesting should apply broadly. For mid-continent mallards, the current AHM models predict K = 11.5 million (i.e., the average population size in the absence of harvest and under average Canadian pond numbers) (Fig. 2.4). If this population were harvested at an annual rate of about 12% (on adult males), the average breeding population size would fall to about 5.9 million, recruitment would be higher than natural mortality, and the sustainable annual harvest would reach 1.35 million mallards. This corresponds to the apex of the yield curve. If the harvest rate were increased beyond 12%, the average population size would continue to take on lower values, but the sustainable annual harvest would drop as well. Thus, given our current understanding of mallard population dynamics, the maximum sustainable annual harvest occurs when the population size averages 5.9 million birds (under average pond numbers).

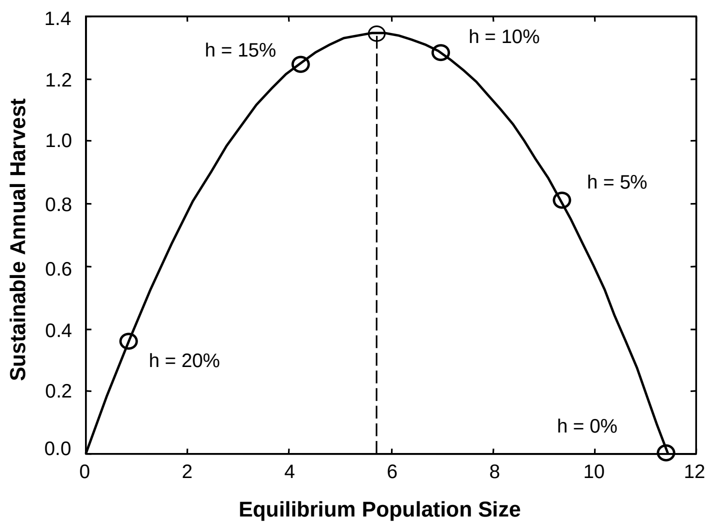

Figure 2.4. Five possible fixed-harvest-rate strategies for mid-continent mallards, each of which would result in a unique equilibrium population size. The maximum sustainable harvest is at the apex of the yield curve at an annual harvest rate of about 12% (on adult males).

In this model of mallard population dynamics, population size depends on the harvest policy and in particular on the harvest rate. In this construct, it should be possible to design a harvest policy to achieve any desired point on the yield curve. For example, if a management policy is chosen whose sole objective is to maximize sustainable harvest, then that policy will seek to hold the mallard population at around 5.9 million birds. On the other hand, a harvest policy could be chosen to hold the population around 8.8 million, which represents the Plan objective of 8.2 million plus an objective of 0.6 million mallards in Minnesota, Wisconsin, and Michigan. However, this policy might be accompanied by a loss of about 30% of the maximum sustainable harvest. The current AHM models and weights suggest that some harvest opportunity must be foregone to keep the mallard breeding population closer to the Plan objective. In effect, current harvest policy splits the difference between harvest rates that would maximize harvest at a breeding-population size of 5.9 million and that which that would hold population size near the Plan objective of 8.8 million.

At this point, a caveat about the concept of "maximum sustained yield" (MSY) is warranted. In fisheries management, policies sometimes were implemented that attempted to manage at the apex of the yield curve and, notably, to extract a *fixed* annual harvest. For reasons that are now apparent, this MSY approach was too simplistic and in some cases proved detrimental to fisheries resources (Punt and Smith 2001). The shortcoming of the traditional MSY approach was in its failure to account for variable environmental conditions and thus for temporal variation in harvest potential. We emphasize that the application of harvest theory we present here for waterfowl is not to be confused with the traditional MSY approach. Modern harvest management relies on state-dependent harvests (i.e., harvest levels that are managed in accordance with uncontrollable changes in population size) or, at a minimum, a constant harvest *rate*, which ensures that harvest is proportional to population size.

<u>The Role of Habitat in Determining Sustainable Harvests</u>

Clearly, harvest policy can affect whether population objectives of the Plan are met, irrespective of the success of the Plan's habitat conservation efforts. Conversely, Plan activities can influence harvest potential and therefore harvest-management policy. For example, conservation efforts could increase the intrinsic productivity of birds, as well as the carrying capacity of the landscape, thereby expanding the yield curve. Figure 2.5 depicts a situation in which enough habitat is restored to increase K to 16 million mallards (instead of the current estimate of 11.5 million). Under this scenario, we predict the maximum sustainable harvest to occur when the population size is about 8 million mallards (instead of 5.9 million). Alternatively, habitat could be lost, shrinking the yield curve and depressing the harvestable surplus. This loss of habitat that reduces K to 8 million mallards would result in the maximum sustainable harvest being attained at a breeding population of 4 million birds. These examples underscore three important points:

(1) habitat management leading to an increase in productive capacity will increase the population size at which harvest is maximized, as well as increase the size of the maximum sustainable harvest;

(2) habitat loss will have the opposite effect; and

(3) the observed population size can be used for evaluating Plan success *only* if there is an explicit accounting of harvest levels.

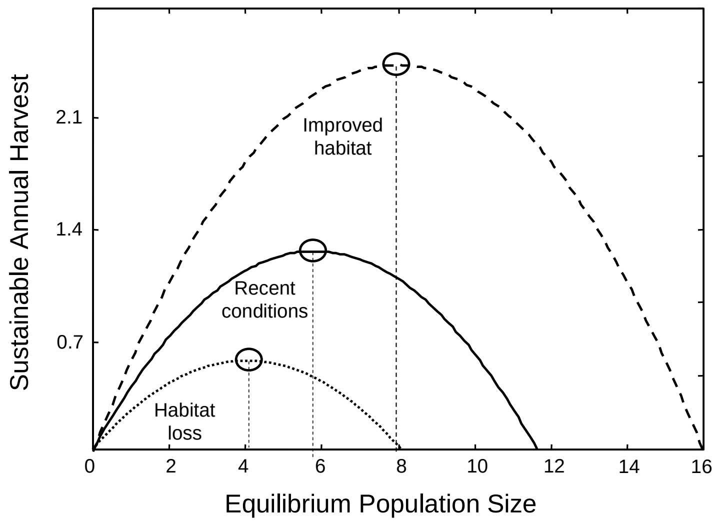

Figure 2.5. Sustainable annual harvest as a function of equilibrium population size under changing habitat conditions. The solid curve is identical to Fig. 2.4. The dashed curve represents the sustainable harvest if the carrying capacity is increased to 16 million mallards, whereas the dotted line depicts the sustainable harvest if the carrying capacity is reduced to 8 million birds. Maximum sustained yield is shown by the circles at the apex of each curve.

III. Integrating Harvest and Habitat Management

Interpreting the Plan's Population Objectives

To harmonize the objectives of harvest and habitat management, we first review some of the guiding principles of the original North American Waterfowl Management Plan. These principles were mostly implicit, but they are relevant to the task at hand.

- A fundamental goal of the Plan is to satisfy the demand for hunting opportunity, conditional of course on sustainable waterfowl populations.

- Hunting, or harvest management, should play a role, along with habitat conservation, in achieving Plan population objectives. The original Plan prescribed harvest regulations for different duck population levels, although these prescriptions were later removed. Consequently, the roles of harvest and habitat management have evolved in a less coordinated fashion than may have been intended by the original Plan, with population objectives now largely assumed to be met through the enhancement of habitat, rather than through (or is spite of) changes in hunting regulations.

- The framers of the Plan clearly understood the dynamic nature of waterfowl habitats, particularly in the Prairie Pothole Region. This recognition led them to couch population objectives in terms of "average environmental conditions." However, framers of the Plan did not have our advantage of hindsight and so may not have recognized that pond numbers during the 1970's were well above the long-term average. This implies that meeting Plan population objectives under average water conditions will require substantive improvements in other, more controllable features of habitat (perhaps even more so than the framers recognized).

In the following text, we interpret Plan population objectives in light of harvest theory and our evolving understanding of waterfowl population dynamics. We examined three alternatives that represent possible interpretations of the original Plan population objectives for ducks, using mid-continent mallards as an example. We again emphasize that mallards serve only as a convenient example, and that the concepts are more broadly applicable. We use the abundance of mallards from the traditional survey area (TSA) and from Minnesota, Wisconsin, and Michigan (Lake states), resulting in a Plan objective for mid-continental mallards of 8.8 million (8.2 million in TSA plus 0.6 million in the Lake states). All references to harvest and population levels are based on the most current population models and weights used in the AHM process.

We see three possible interpretations of the original Plan population objectives:

(1) The Plan objectives represented population sizes at which harvest could be maximized. The JTG viewed this as an unlikely interpretation for several reasons. Waterfowl harvest management traditionally has been risk-averse. We believe it unlikely that the management community was consciously pursuing maximum harvests in light of the limited understanding of population dynamics and the impact of hunting. Moreover, given that limited understanding, it would have been a remarkable coincidence had the Plan objectives corresponded with the population sizes necessary to maximize harvest. Finally, if the Plan objectives were intended to represent those necessary to maximize harvest, then the associated carrying capacity (K) of mid-continent mallards would have been about 18 million (Fig. 3.1). This seems a rather high value, even considering the good habitat conditions of the 1970s.

(2) The Plan objectives represent the carrying capacity of the landscape. The JTG viewed this as the least likely alternative. If the carrying capacity truly were 8.8 million mallards in the 1970s, then the only plausible explanation given current models of mid-continent mallards is that K has increased substantially in the last 20-30 years. Given on-going loss and degradation of waterfowl habitats, this was deemed unlikely (Fig. 3.2). And because the Plan objective of 8.8 million mallards was met in the presence of significant harvest, we conclude that the Plan objective must have been less than K.

(3) The Plan objectives represent population sizes which realistically can be attained by habitat conservation programs and which provide for satisfactory levels of hunting. Given the above arguments, we believe that the Plan objective for mallards (and more generally for ducks) must have been on the right shoulder of the yield curve in the 1970s. Therefore, it seems reasonable to conclude that the Plan seeks to expand the yield curve so that the population objective falls somewhere higher on the right shoulder of the curve (Fig. 3.3). The yield curve of the 1970s for mallards suggests that K was 23% higher than now (due to higher than average pond numbers in the 1970s) and that the Plan objective was a population size at which most (94%) of the maximum sustainable harvest

could be achieved (Fig. 3.4).

Throughout this discussion we have made reference to “recent conditions” of the environment, and we understand the questions this might prompt in the reader’s mind. Thus, some clarification is warranted. For mid-continent mallards, a model set was constructed using data from the period 1961-1995. Since 1995, the weights on the 4 models have been updated annually by comparing the observed BPOPs with the predicted BPOPs from each model. The yield curve we are labeling “recent conditions” is based on the 2006 weighted average model (with Canadian ponds set at their 1961-1995 average value). To the extent that (1) the original model set circumscribes the range of possible states to which the system could have moved, (2) the monitoring system is precise enough to keep up with changes in the system, and (3) the average number of ponds has remained the same, the yield curve does represent our estimate of productive capacity under “recent conditions.” For example, if there has been net loss of continental carrying capacity because of loss of breeding habitat, we would expect the model weights to shift toward the strongly density-dependent models (which have lower carrying capacity), and the derived yield curve to shrink accordingly. That said, it is clear that the monitoring system is not precise enough to track changes in continental carrying capacity (or the yield curve) over short (i.e., annual) time intervals, nor do the current models include all of the relevant geography (e.g., U.S. ponds) or features like grassland habitat that are known to be important determinants of mallard recruitment.

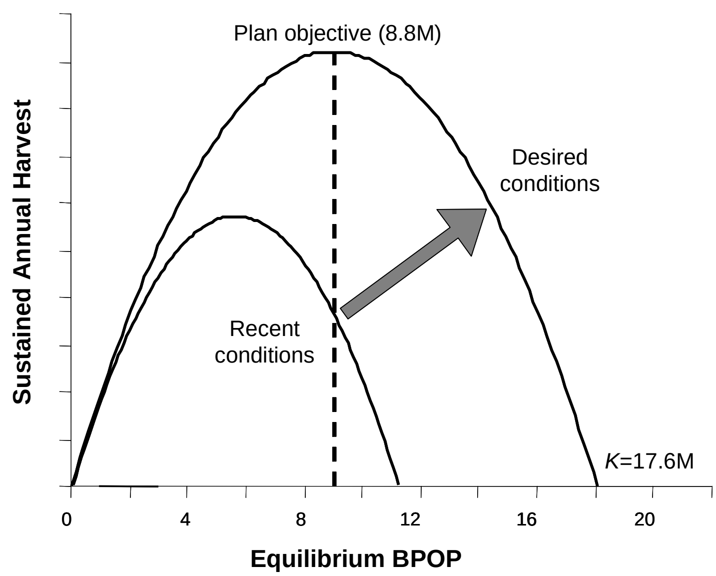

Figure 3.1. If the Plan population objective for mid-continent mallards represents the population size at which harvest can be maximized, the carrying capacity (*K*) would have to be increased substantially (based on current AHM models and their weights).

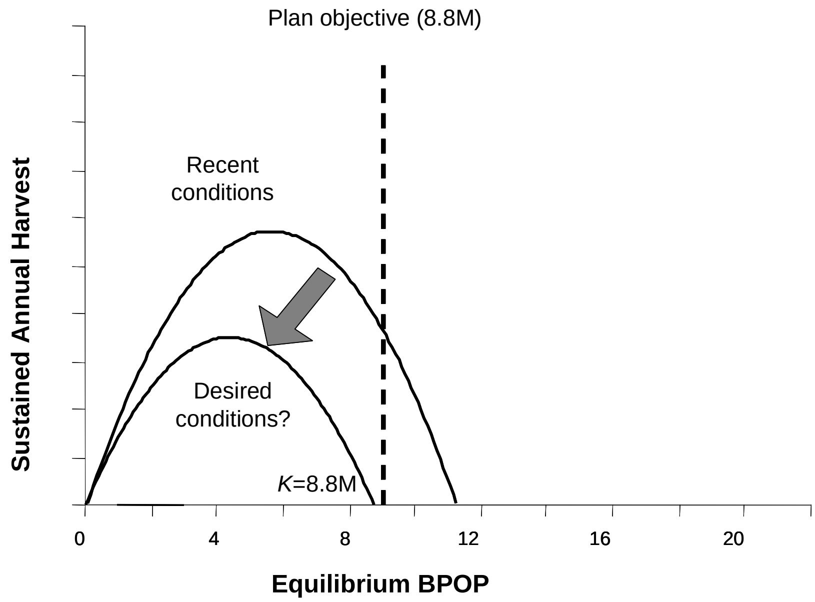

Figure 3.2. If the Plan population objective for mid-continent mallards represents the carrying capacity of the 1970s, the carrying capacity has increased over the last 20-30 years.

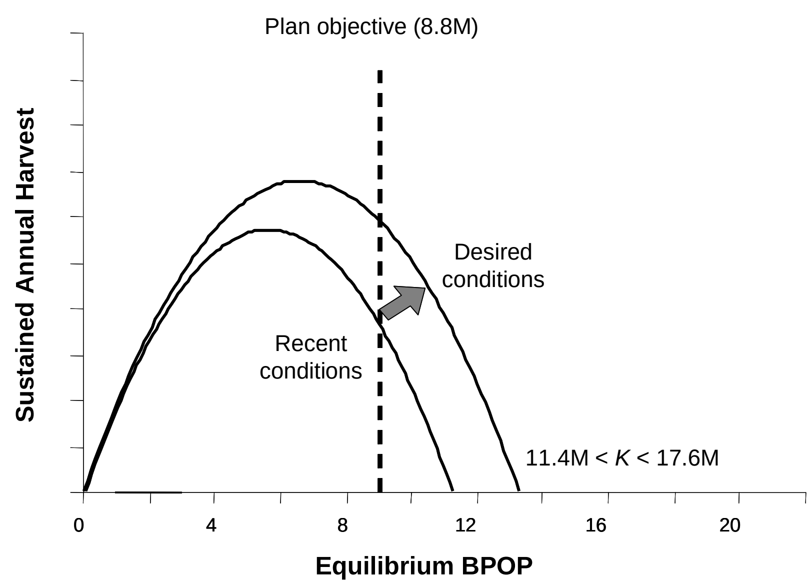

Figure. 3.3. A plan population objective for mid-continent mallards that is less than carrying capacity (*K*), but greater than that necessary for maximizing harvest, is consistent with the principles of the original Plan.

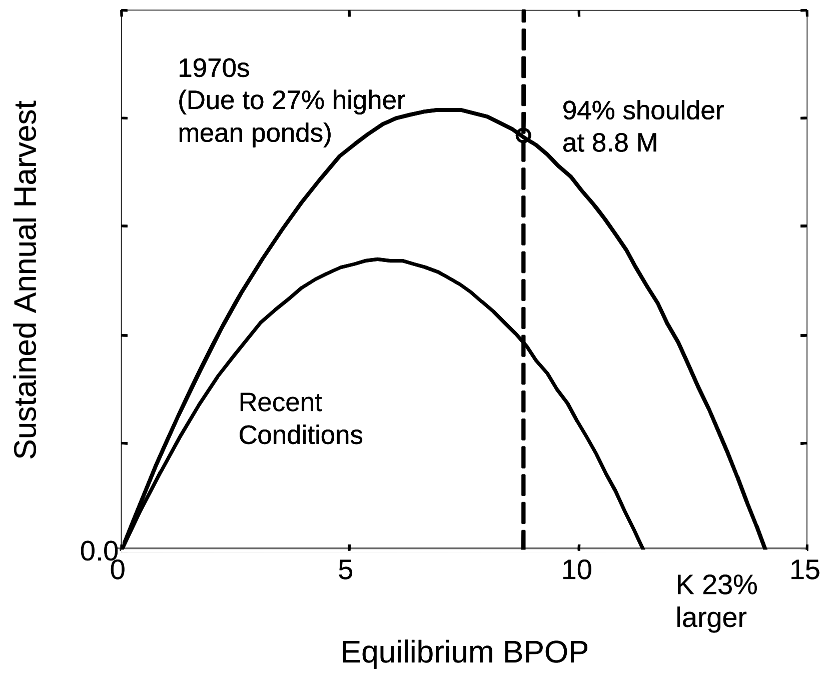

Figure. 3.4. The yield curve of the 1970s for mallards suggests that *K* was 23% higher than now (due to higher than average pond numbers in the 1970s) and that the Plan objective was a population size at which most (94%) of the maximum sustainable harvest could be achieved.

<u>Integrating Harvest and Habitat Management</u>

We believe a coherent and integrated program of habitat and harvest management would be characterized by:

- *Plan population objectives that correspond to population levels sought under an optimal harvest policy*; this element of coherence ensures that observed breeding-population size can be used to directly assess achievement of Plan objectives at large spatial and temporal scales;

- *a harvest policy that seeks a constant proportion of the maximum sustainable yield, whatever that maximum may be*; this element of coherence ensures that harvest policy does not chase population objectives irrespective of uncontrollable changes in short-term environmental conditions; and

- *a common assessment framework for examining the simultaneous effects of varying harvest and habitat conditions on waterfowl abundance*; this element promotes a shared understanding of waterfowl population dynamics, as well as coordinated development and application of monitoring and assessment programs.

Achieving coherence will require managers to jointly address three critical policy questions:

(1) *Aside from those cases of over-abundant waterfowl populations, how much does the Plan seek to expand the yield curve and increase K?*

(2) *What location on the yield curve (on average) is sought by harvest managers*? This location will be on the right shoulder for those populations that we want to maintain at a relatively high level and on the left shoulder (i.e., past the point of maximum sustainable yield) for populations whose sizes we want to maintain at a lower level.

(3) *As the yield curve expands or shrinks over time, what role, if any, should harvest management play in reaching and/or maintaining populations at Plan objectives?*

Based on a review of the principles of the original Plan and on waterfowl population dynamics as we currently understand them, we examined a number of alternatives for integrating harvest and habitat management. Our preferred alternative has come to be known as a "*shoulder strategy*." In this approach the goal of harvest management for most waterfowl populations would be to seek sustainable harvests that lie on the right-hand shoulder of the yield curve (i.e., a fixed proportion of the maximum sustainable yield) and the goal of habitat management would be to expand the yield curve such that the Plan goal falls at the same point on the shoulder.

Our preferred alternative positions most Plan population objectives below *K* but above the population size for maximizing harvest, and thus seems consistent with the original intent of the Plan (Fig. 3.5). Moreover, this alternative likely represents a more feasible expansion of habitat than that necessary to support maximum sustainable harvests at Plan population objectives. Harvest policy would seek something short of maximum yield, affording a cushion against uncertainty, potentially fewer species-specific regulations, and possibly less stringent monitoring and assessment demands. Importantly, harvest would not be foregone in a potentially futile attempt to attain the Plan population objectives in the face of adverse, but uncontrollable, environmental conditions. Finally, harvest and habitat management objectives would be congruent in that population size could be used as a direct measure of Plan success at large scales.

We recognize, of course, that some managers may wish to maximize sustainable harvests (i.e., achieve harvests at the apex of the yield curve), with the Plan objectives representing population sizes corresponding to those levels of sustainable yield (Fig. 3.6). The desired coherence of harvest and habitat management objectives would be attained, but this alternative implies a substantial increase in carrying capacity (at least for mallards) and a liberalization of current harvest policy. Moreover, we believe that maximization of harvest is generally not appropriate as a management objective (except in the case of over-abundant species). Our ability to estimate maximum sustainable yields for various species and our ability to explicitly account for uncertainty in such estimates has increased dramatically with AHM and the development of new assessment methods. However, our capacity to generate these estimates and construct coherent management strategies around them still encompass a small fraction of the species that are subject to harvest during general hunting seasons. And while we understand a great deal about mallard ecology, we still don't understand the mechanisms by which density dependence operates and to what extent it may be operative in the mortality and reproductive processes. Not surprisingly (at least in retrospect), AHM has taught us very little about these processes and the prospect for learning more from the AHM process itself is not particularly good (Johnson et al. 2002). Perhaps of more concern is the empirical evidence that maximum yield levels have changed over the last several decades for three important species in the sport harvest – pintails, black ducks, and scaup – likely as a result of environmental factors affecting carrying capacity. Whether an adaptive harvest strategy can anticipate or even keep pace with such system changes is a topic of growing concern. The advisability of seeking to manage for maximum levels of harvest in such evolving systems is debatable.

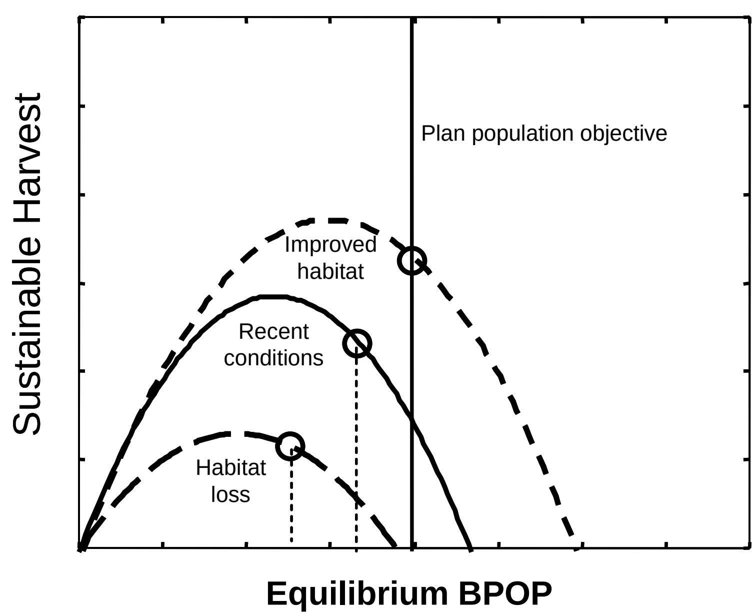

Figure 3.5. The preferred alternative for integrating management programs for most waterfowl species is one in which the goal of harvest management would be to seek sustainable harvests that lie on the right-hand shoulder of the yield curve (i.e., a fixed proportion of maximum sustainable yield) and the goal of habitat management would be to expand the yield curve such that the Plan population objective falls at the same relative point on the shoulder.

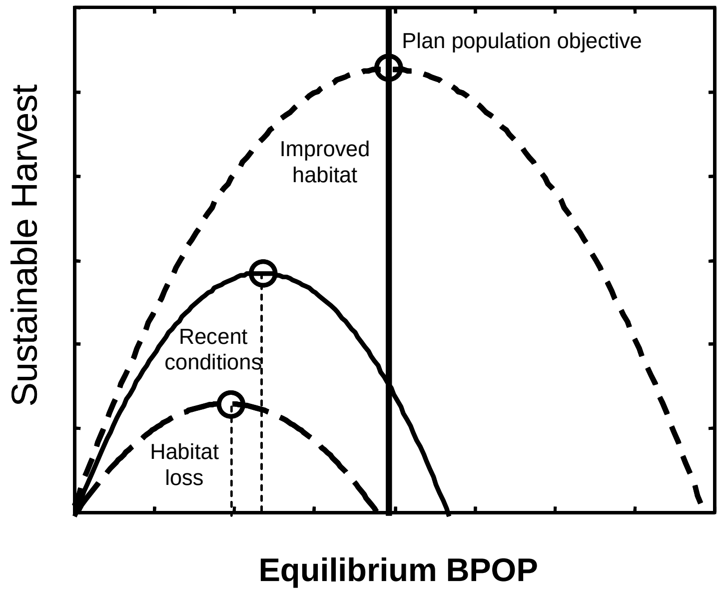

Figure 3.6. An alternative for unifying management programs in which the goal of harvest management is to maximize harvest and the Plan objective represents a desired population size necessary to increase maximum sustainable harvest.

Another concern about attempts to maximize harvest involves the harvest of species other than mallards. To date, mallard harvest and population size have been the principal focus of AHM as an operational protocol for setting general hunting seasons. This practice subjects a large number of duck species to a common sport harvest. While this may have been a rational approach in the past, we believe it is less so now because many duck species no longer show a high degree of correlation in abundance with mid-continent mallards, and several species have experienced severe long-term declines. Thus, there is growing concern that the liberalization in hunting regulations associated with AHM (especially since 1997) is subjecting some species and populations to excessive harvest pressure; as a consequence there has been an increasing number of species-specific harvest strategies that have been difficult to develop, administer, and evaluate, and so far it is unclear whether they have increased or decreased hunter satisfaction.

We believe an even less desirable alternative is essentially the status quo under AHM, in that the goal of harvest management would be to maximize harvest, subject to a constraint on harvest whenever population size is below the Plan objective. The objective of habitat management would be to increase the yield curve such that the Plan goal represented the population size at which harvest could be maximized (thus resulting in no penalty on harvest opportunity). This alternative affords little coherence between management programs and represents a substantial increase in the necessary carrying capacity (at least for mid-continent mallards). Most importantly, harvest would play a major role in attaining Plan population objectives, irrespective of short-term variability in habitat conditions.

IV. Detailed implications of the preferred option

In this section, we discuss the implications of a shoulder strategy for both harvest and habitat management. We use mid-continent mallards as the case study to explore these implications, but we believe the general patterns should hold more broadly. First, we explore the habitat implications of a shoulder strategy, particularly regarding how habitat management can affect carrying capacity. Second, we discuss how the choice of a shoulder point would affect the harvest strategy and its performance. Third, we look at how the choice of a desired shoulder point involves a trade-off between habitat and harvest goals, and motivates a broader discussion of waterfowl management goals.

Detailed Habitat Implications

1. The influence of habitat change on demography

To illustrate how changes in demography could influence carrying capacity, we use a simple model in which the equilibrium population size is determined by the balance between birth rates (recruitment) and death rates (mortality) (Fig. 4.1). Both vital rates are assumed to be density-dependent. As the population size increases, the recruitment rate decreases while the mortality rate increases. We depict mortality rate in Fig. 4.1, but more accurately, the line for mortality represents the increase in recruitment required to offset a given increase in mortality (i.e., both functions are measured in terms of recruitment). For simplicity, we assume that these relationships are linear, although we acknowledge that the functional forms of these relationships may differ (see section V).

Carrying capacity (*K*)—the equilibrium population size in the absence of harvest—is determined by the point where recruitment balances mortality (i.e., the intersection of the line for recruitment and that for mortality). Given this, we can explore how improvements in habitat quality or quantity influence recruitment and survival, and thereby prescribe *K*. The carrying capacity could be influenced in one of four ways, involving changes in: (i) the intercept or (ii) slope of the recruitment function, or (iii) the intercept or (iv) slope of the mortality function (Fig. 4.2). Changes in these vital rates, in turn, depend on the relative influence of habitat quality versus habitat quantity, and on the degree of density-dependence. The influence of habitat quality vs. quantity turns out to be an important consideration and differs on the breeding grounds relative to wintering and migration areas, as we illustrate below.

Although *K* is expressed as a continental population parameter, the ways managers might influence *K* are mainly by regional actions designed to affect important population vital rates. In the next two sections, we explore scenarios for how we would attempt to increase *K* using practices employed at the joint venture level. This is important for understanding the implications of our general models and to stimulate the joint ventures to consider how they might contribute most effectively to conserving or enhancing carrying capacity.

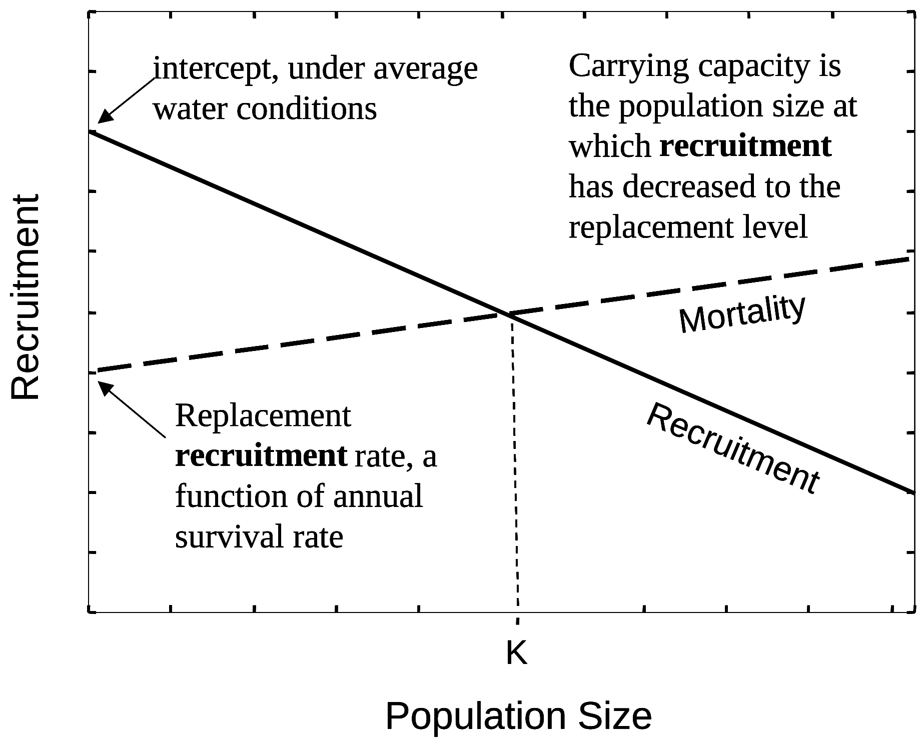

Figure 4.1. A simple model illustrating the influence of population size on mortality and recruitment where mortality and recruitment are assumed to be linear functions of density. Carrying capacity (*K*) is defined as the equilibrium population size (i.e., the point at which recruitment rate balances mortality rate) in the absence of harvest.

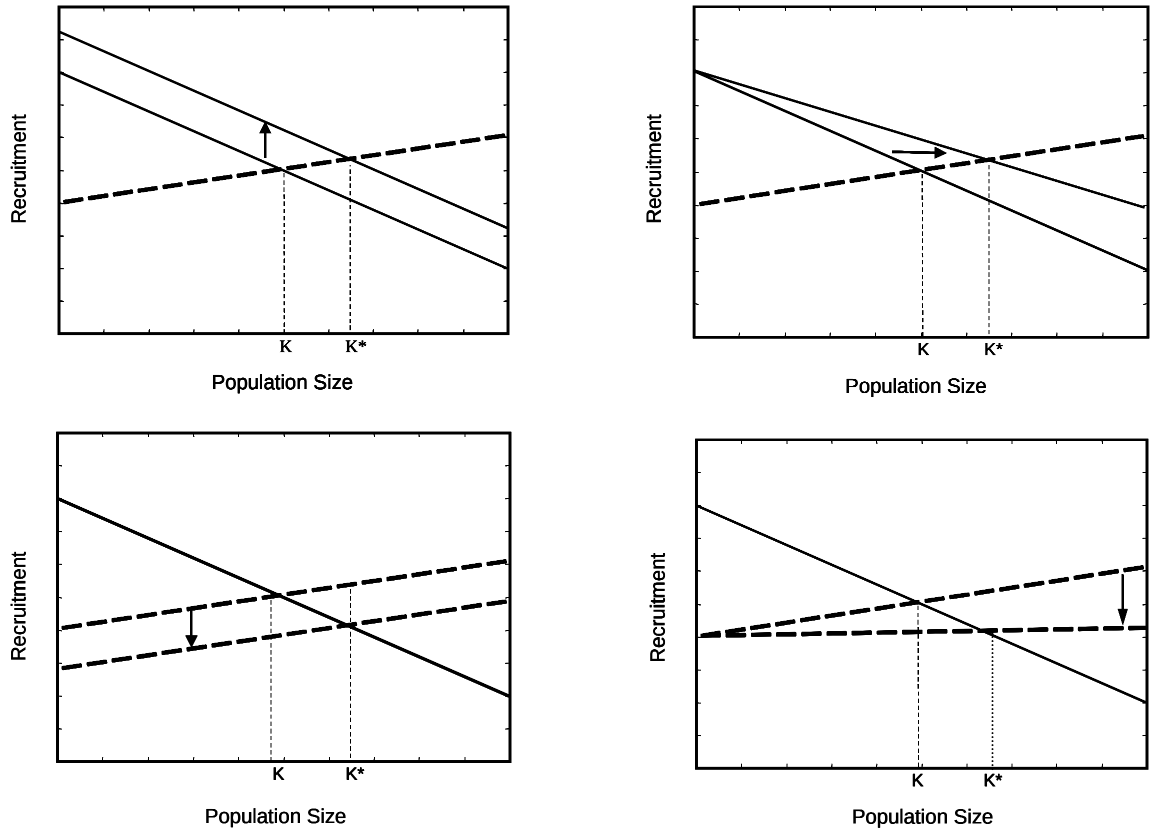

Figure 4.2. Increasing carrying capacity (*K**) through improvements to the quality and quantity of habitats used throughout the annual cycle. **A** (top left) Increasing recruitment by improving the quality of habitats used throughout the year. This mechanism for increasing *K* is largely density independent. **B** (top right) Increasing recruitment by improving the quantity of habitat on the breeding grounds. This mechanism for increasing *K* is largely density dependent. The effect in this model (assuming linearity) is disproportionate. Increases to recruitment may not be manifest at lower population sizes because at lower population sizes resources are not limited. **C** (bottom left) Decreasing annual mortality rates in a density-independent manner. This mechanism for increasing *K* might occur through improving habitat quality throughout the annual cycle. **D** (bottom right) Decreasing annual mortality rates in a density-dependent manner. This mechanism for increasing *K* differs from that depicted in Fig. 4.2C in that changes to *K* occur disproportionately at higher population sizes.

2. Breeding areas

Habitat conservation actions in breeding areas potentially influence *K* through any of the four mechanisms depicted in Fig. 4.2. Here, we explore what those mechanisms might look like for a breeding area such as the prairie pothole region (PPR). At the outset, a brief comment about density-dependence is warranted. To our knowledge, small-scale (e.g., 4 mi^2-plot) empirical studies have thus far been unable to demonstrate local, density-dependent effects in the PPR. Evidence exists, however, for density-dependence in some duck populations at the continental scale (Vickery and Nudds 1984, Jamieson and Brooks 2004, Viljugrein et al. 2005). If this is the case, the mechanism likely occurs at the regional level through a displacement effect (Dzubin 1969). That is, when populations are larger, more birds are forced into suboptimal habitat in which breeding is less successful (e.g., Smith 1970, Calverley and Boag 1977). For the density-dependent mechanisms below, then, we need to be thinking about landscape configuration across the whole region.

a. The intercept of the recruitment rate function is increased (Fig. 4.2A). Improvements in habitat enhance recruitment equally at all levels of population abundance (i.e., the effect is density-independent). On the breeding grounds, this is likely to be a function of enhanced habitat quality such that, at all densities, birds realize higher reproductive success. Actions on breeding areas that increase recruitment irrespective of population density involve improving habitat conditions in existing habitat. For the prairie pothole region (PPR), for example, restoring grassland, reducing nest predation by deploying safe nesting structures or predator management, and promoting winter cereals as alternatives to spring-seeded crops are all examples of interventions that increase nesting success and thus habitat quality (e.g., Reynolds et al. 2001, Stephens 2004).

b. The slope of the recruitment rate function is increased (Fig. 4.2B). Recruitment is improved disproportionately at higher abundances (i.e., the effect is density-dependent). Such a scenario might best reflect an increase in the quantity of habitat. At low abundances, no effect on recruitment is observed. As abundance increases, resources become limited and recruitment is reduced. Provision of more habitat (resources) alleviates this limitation, increasing recruitment. Extensive efforts have been employed to secure additional wetland and nesting habitat for prairie-nesting waterfowl through a wide variety of acquisition, restoration and easement programs (Ryan et al. 1998, Reynolds et al. 2001, Tori et al. 2002).

c. The mortality intercept is reduced (Fig. 4.2C). Here, habitat improvements reduce mortality equally at all levels of abundance (i.e., density-independence). In the PPR, the greatest source of annual mortality for females is mortality associated with nesting, and many management actions that increase nesting success also increase hen survival. The extent to which such mortality is density-dependent is unknown. Ironically, management actions that might stimulate greater reproductive effort could actually increase breeding-season mortality and reduce carrying capacity if survival is density-dependent or if increased nesting effort by females results in increased exposure to predation risk.

d. The mortality slope is reduced (Fig. 4.2D). In this case, changes in habitat enhance survival disproportionately at higher population sizes (i.e., density-dependence). This could arise through a decrease in predator or disease-mediated mortality if survival rates are compromised when birds are concentrated or at higher densities.

We recognize the ongoing loss of grasslands and wetlands in the PPR, and acknowledge that conservation interests will be challenged to maintain, let alone enhance, the current carrying capacity of this region. For example, within the Prairie Pothole Joint Venture, contracts on 4 million acres of CRP grasslands are set to expire during 2007-2010. Only 22 million acres of native prairie remain, and we are losing about 2.5% per year. Further, of the 7.3 million acres of wetlands in the U.S. PPR, only 1.5 million acres (20%) are protected by easement, and the percentage protected in Canada is even lower. For these reasons, many partners in the PPR are beginning to prioritize protection of existing habitat over restoration of degraded habitat. It is important to recognize, however, that protection of existing habitat preserves *K* but does not enhance it. We must consider carefully, therefore, any cohesive Plan-AHM strategy that calls for increasing continental *K*. This may present the single greatest challenge inherent in truly integrated waterfowl management objectives.

3. Wintering and migratory areas

Habitat conservation actions in migration and wintering areas also potentially influence *K* through the four mechanisms outlined in Fig. 4.2. However, on non-breeding areas, the ability to attribute changes in recruitment or mortality specifically to either habitat quantity <u>or</u> quality is more problematic. For example, provision of more foraging habitat (increased quantity) may improve overall body condition and reduce foraging costs. This could influence the mortality intercept (lowering mortality at all densities), the mortality slope (lowering mortality disproportionately at high densities), the recruitment intercept (if higher body condition during winter translates into greater reproductive success on return to the breeding grounds), and/or the recruitment slope (if the influence of winter habitat on seasonal body condition is greater at high densities). In a parallel manner, improvements in habitat quality (e.g., providing more or higher quality food per unit area) could have similar effects. It is also plausible that the effects of habitat quality or quantity on survival and/or recruitment are density-independent below a given population threshold, above which the effects are manifest in a density-dependent manner. Disentangling the influence of habitat quality vs. quantity on vital rates will therefore be challenging for managers on non-breeding areas, and management efforts will likely influence both (Nichols and Hines 1987, Reinecke et al. 1987)

a. The intercept of the recruitment rate function is increased (Fig. 4.2A). Actions on migration and wintering areas that improve recruitment irrespective of population density generally assume a relationship between seasonal body condition and subsequent reproduction. Habitat actions lead to an improvement in body condition such that all birds (at any density) arrive on the breeding grounds in better condition and have higher success. To do so, management strategies employed in non-breeding areas focus on increasing both habitat quantity (e.g., restoring hydrology to drained wetlands or increasing acreages of flooded rice fields) and habitat quality. Increasing habitat quality is accomplished through increased waterfowl food production on existing habitats (e.g., improving seed production in moist soil management units) and actions to remediate contaminants. Strategies may also involve the spatial arrangement and density of food resources, and the provision of cover, among other things. If food resources are patchy and thin, yet extensive, there might be enough energy for the birds present, but they might have to expend considerable effort to obtain it. In such a case, increasing the density and arrangement of food resources to minimize travel time could allow greater improvement in body condition, improving impacts to subsequent recruitment. Locating related habitat features, such as safe and protective roosting sites, near to food resources, could further influence condition and subsequent recruitment.

Given urban development pressures, the threat of relative sea level rise to coastal wetlands, future water availability concerns, and other ongoing loss of key wintering habitats, a very reasonable goal for many wintering joint ventures will be to simply maintain current habitat levels. Consequently, strategies to maintain habitat quantity and quality are also important. These actions include incentives for winter flooding on managed agricultural lands, addressing shoreline protection and hydrologic threats to coastal wetlands, protecting intact hydrologic systems, maintaining moist soil management expertise, maintaining incentives for the availability of some un-harvested grain, and prevention of contamination.

b. The recruitment slope is increased (Fig. 4.2B). Actions on migration and wintering areas that improve recruitment disproportionately at higher populations are primarily those that relate to the provision of foraging habitat with the assumptions that: (1) at least under some conditions, the availability of food restricts over-winter body condition and subsequent recruitment, and (2) increased competition for limited food resources occurs at high population densities. Strategies, actions, and tools relating to this potential mechanism to impact K are generally the same as those listed above to improve or maintain recruitment irrespective of population density. The only difference is that influences of non-breeding habitat on recruitment are manifest disproportionately at high population densities.

c. The mortality intercept is reduced (Fig. 4.2C). Actions on migration and wintering areas that improve survival irrespective of population density are the same as those listed above to improve or maintain recruitment irrespective of population density, and assume a relationship between condition and survival.

d. The mortality slope is reduced (Fig. 4.2D). Actions on migration and wintering areas that improve survival at high population densities are generally the same as those listed above to improve or maintain recruitment irrespective of population density. The only difference is that influences of non-breeding habitat on survival are manifest disproportionately at high population densities. One additional strategy, though, would be to influence the distribution of habitats to reduce waterfowl concentrations and associated disease risks.

In summary, to change the yield curve, we need to change the continental carrying capacity for a species, through effects on underlying demographic processes and rates. The changes we effect can be density-independent or density-dependent in nature, or both, and the demographic impact of those changes is affected by the mechanism by which they operate.

In principle, the general approaches to increasing carrying capacity (Fig. 4.2) should be the same for all populations and habitats. To be most effective, however, management interventions ought to be targeted primarily to those places and times in the annual cycle where habitat is believed to be most limiting for individual waterfowl populations. This may well differ among species and vary over time such that those places and processes most limiting in some years will be less limiting in other years. We also predict that actions that exert their influence in a density-independent manner (i.e., changing recruitment or survival intercepts) might generally be most effective, although factoring in differing costs may ultimately influence that conclusion. Whether a joint venture is focused primarily on breeding habitat, wintering habitat or migration habitat, the challenge is to sort through empirical evidence to determine where resource limitations exist and consider what might be done to affect recruitment and/or survival rates in each region. Erecting explicit hypotheses about limiting factors and predicted effects of conservation measures on vital rates, and ultimately *K*, would provide a useful framework for planning and assessment. This would also enable simulation studies of alternative increases (or decreases) in *K* that might result from setting different BPOP and harvest yield objectives for those same populations and contribute to the technical integration of harvest and habitat management.

4. Quantitative assessment of required demographic change

We have argued above that the Plan goals can be interpreted as desired expansions of the yield curve, hence as desired increases in continental carrying capacity. To understand the implications of various magnitudes of increase in carrying capacity, we calculated the changes in recruitment and survival rates that would be required to effect those increases using the 2006 mid-continent mallard models (Table 4.1). For example, the continental carrying capacity could be increased by 10% by increasing the recruitment intercept by 4%, the recruitment slope by 10%, or the annual survival rates (in the absence of harvest) by 2.3% (or by combinations of lesser amounts of all three). Following the arguments in the preceding discussion, a 4% increase in the recruitment slope can be interpreted as a 4% increase in breeding habitat quality, or an improvement of winter habitat quality that leads to a 4% increase in recruitment. A 4% increase in recruitment slope can be interpreted as a 4% increase in breeding habitat quantity. These percentages, of course, do not necessarily indicate the most effective mechanism for increasing continental carrying capacity. While a 10% increase in *K* only requires a 2.3% increase in survival but a 4% increase in breeding habitat quality, it may be the case that it is easier to achieve this increase through breeding habitat quality. Further, many possible habitat management actions may affect more than one demographic parameter at a time. Nevertheless, Table 4.1 is meant to provide one step toward a better understanding of what changes in demographic rates would be necessary to increase continental carrying capacity for mid-continent mallards. Similar patterns may hold for other species.

Table 4.1. Demographic changes required to increase continental carrying capacity. For a given level of desired change in carrying capacity, the corresponding required changes in the recruitment intercept (see Fig. 4.2A), recruitment slope (see Fig. 4.2B), and survival rates (see Fig. 4.2C) are shown. These results were calculated for the average mid-continent mallard models and associated 2006 weights.

	Required Change in Parameter		
Desired Change in Carrying Capacity	Recruitment Intercept (e.g., via Breeding Habitat Quality)	Recruitment Slope (e.g., via Breeding Habitat Quantity)	Survival Rate
0.0 %	0.0 %	0.0 %	0.0 %
2.5	1.0	2.5	0.6
5.0	2.0	5.0	1.2
7.5	3.0	7.5	1.7
10.0	4.0	10.0	2.3
12.5	5.0	12.5	2.9
15.0	6.0	15.0	3.6
17.5	7.0	17.5	4.2
20.0	8.0	20.0	4.8
22.5	9.0	22.5	5.4
25.0	10.0	25.0	6.1
27.5	11.0	27.5	6.7
30.0	12.0	30.0	7.4
32.5	13.0	32.5	8.0
35.0	14.0	35.0	8.7
37.5	15.0	37.5	9.3
40.0	16.0	40.0	10.0

Detailed harvest implications

The adaptive harvest management (AHM) program, by which recommendations for mid-continent mallard regulations are made, derives an optimal harvest strategy from an explicit objective, a set of models, and a set of alternative regulations packages using stochastic dynamic programming. In the course of our work, we have discovered that a shoulder strategy can be implemented by incorporating a cost function into the objective function, and maximizing harvest unit cost, rather than just harvest. We used this approach to assess how the choice of shoulder point affects the optimal strategy and performance metrics for harvest of mid-continent mallards.

If we seek to maximize the long-term cumulative harvest of mid-continent mallards, that is, if we seek to harvest at the apex of the yield curve (100% shoulder) without regard to the Plan objective or any other constraints, we would hold the population size around 6.4M on average, with an average harvest rate of about 11%, and achieve liberal seasons three-quarters of the time (Table 4.2). The optimal harvest strategy, however, is quite knife-edged (Fig. 4.3A), in that the transition from a liberal season to a closed season occurs over a very narrow increment of population size. It would be rare that the restrictive or moderate packages were called for. If, instead, we sought a right shoulder strategy, we would hold the average population size higher, would employ a lower average harvest rate, would largely eliminate the need for closed seasons, and the harvest strategy would be much less knife-edged (Table 4.2, Figs. 4.3B and 4.3C). A 90% shoulder strategy would result in an average population size of 7.4M and an average harvest rate of 0.089. Lower points on the shoulder beyond 90% translate into higher average abundances, lower harvest rates, and proportionally more time in restrictive regulation packages. The change in the optimal harvest strategy as a function of the desired shoulder point is fairly dramatic.

Table 4.2. Expected mean population size (BPOP), harvest rate, and package frequencies for mid-continent mallards under various shoulder strategies using the current objective and under current habitat conditions. These results were calculated by first deriving the appropriate optimal strategy using stochastic dynamic programming, then simulating that strategy for 2000 iterations.

Strategy	**Mean BPOP** (sd)	**Mean harvest rate**	**Package frequencies**			
% shoulder			Closed	Restrict.	Moderate	Liberal
100%	6.44 (1.93)	0.108	12.9 %	4.2 %	5.7 %	77.2 %
95%	6.98 (1.98)	0.098	0.3 %	32.2 %	42.1 %	25.4 %
90%	7.43 (2.06)	0.089	0.2 %	45.1 %	44.8 %	10.0 %
85%	7.80 (2.16)	0.081	0.2 %	57.5 %	40.1 %	2.4 %
80%	8.16 (2.27)	0.073	0.1 %	71.4 %	28.6 %	0.0 %
75%	8.46 (2.44)	0.067	0.1 %	83.7 %	16.2 %	0.0 %
Current	7.45 (1.86)	0.088	9.9 %	37.9 %	7.2 %	45.1 %

Thus, selection of a point on the shoulder of the curve is not a trivial matter. These results beg the question of where the waterfowl management community wants to be on the shoulder of the yield curve. The current AHM objective function (which includes a devaluation of harvest value at abundances below the Plan objective and a closure restriction for population sizes less than 5M [Fig. 4.3D]) approximately seeks a 92% shoulder, although it behaves very differently away from equilibrium than a 92% shoulder strategy would (compare Figs. 4.3B and 4.3D). On the yield curve of the 1970s (Fig. 3.4), the Plan goal (8.8M) falls at about the 94% shoulder, although for this yield curve the carrying capacity is about 23% larger than current, largely owing to the wetter conditions in Prairie Canada during the 1970s.

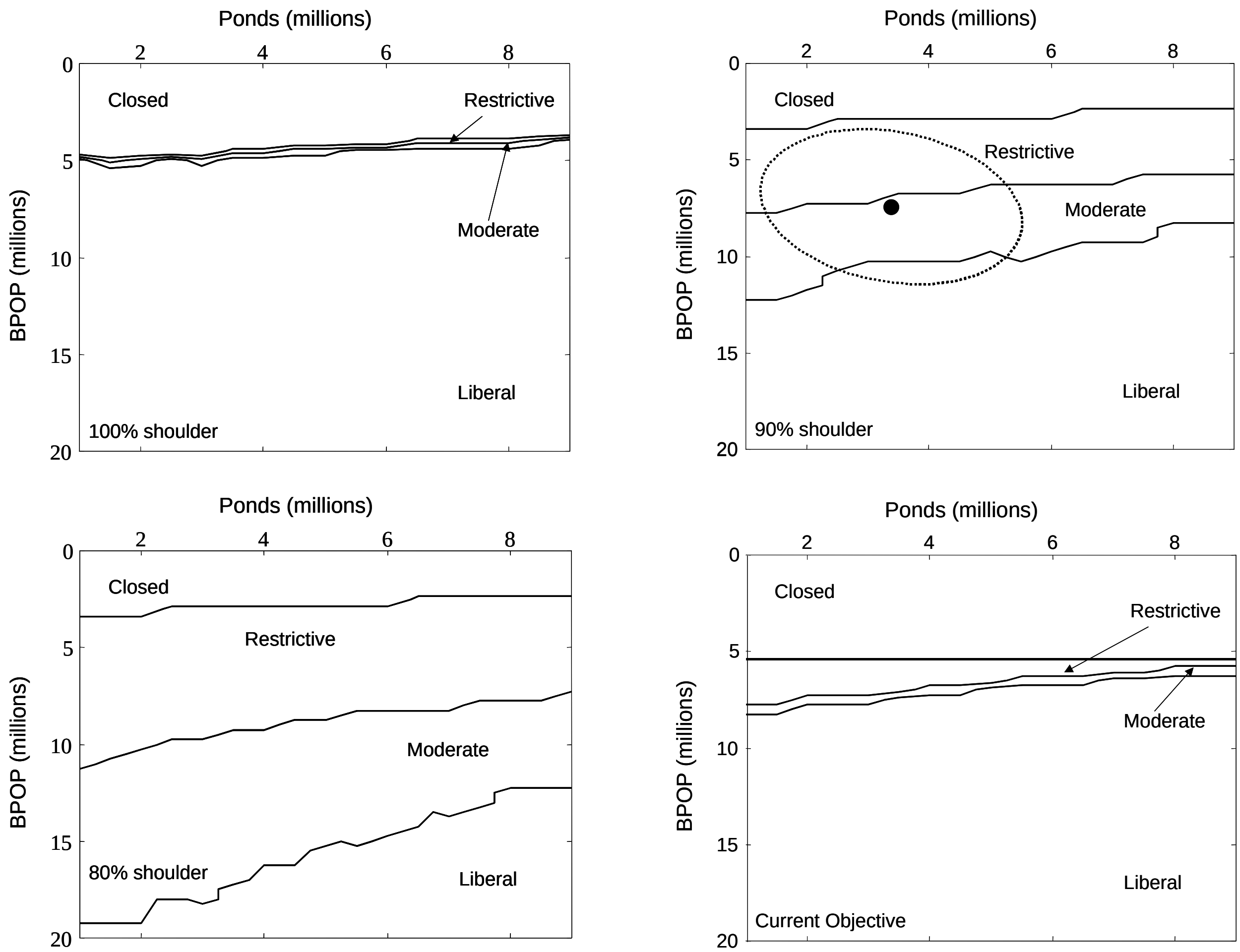

Figure 4.3. Mid-continent mallard harvest strategy, derived under several objective functions. The strategies show the recommended regulatory alternatives (Closed, Restrictive, Moderate, or Liberal) as a function of the current mid-continent mallard breeding population size (BPOP) and ponds in Prairie Canada. These strategies were generated using the 2006 mid-continent mallard AHM models. **A** (top left) Objective seeks maximum sustained harvest (100% shoulder), without a closure restriction, and without the devaluation of harvest at abundances below the Plan objective in the objective function. **B** (top right) Objective seeks 90% shoulder. For comparison to other 90% shoulder strategies in Fig. 4.4, the solid circle shows the expected values for BPOP and Ponds under this strategy; the state of the system is expected to be within the dashed ellipse 95% of the time. **C** (bottom left) Objective seeks 80% shoulder. **D** (bottom right) Current objective function, including a devaluation of harvest at abundances below the Plan goal and closure restriction. This strategy is identical to what is calculated in the 2006 AHM Report (USFWS 2006).

To determine how harvest strategies may change with changes in continental carrying capacity, as driven by the efforts of Plan, we considered a harvest management objective that seeks a 90% shoulder on the curve, and a habitat management objective that seeks to increase carrying capacity so that the 90% shoulder falls at 8.8M (the Plan objective). These objectives would be coherent in the sense discussed in Section 3.2. This would require an increase in carrying capacity of 17% (see “Trade-offs in choosing a desired point on the shoulder” below, Table 4.3). The resulting yield curve and the corresponding optimal harvest strategy depend on the mechanism by which habitat (carrying capacity) is changed. Improving breeding habitat quality (i.e., through an overall increase in recruitment across all densities) provides greater harvest potential than increasing breeding habitat quantity (i.e., an increase in the slope of recruitment against density). Using the 2006 mid-continent mallard models, if we were to increase carrying capacity by 17% through increases in breeding habitat *quantity*, and we employed a 90% shoulder strategy, we could expect to hold the population at 8.7M on average with an average harvest rate of 0.089, liberal seasons 9% of the time and an equal split of restrictive and moderate seasons the rest of the time (Fig. 4.4A). If we were to increase carrying capacity 17% through increases in breeding habitat *quality*, however, we could expect the same average population size, but an average harvest rate of 0.102, liberal seasons 24% of the time, moderate seasons 51%, and restrictive seasons 24% of the time (Fig. 4.4B).

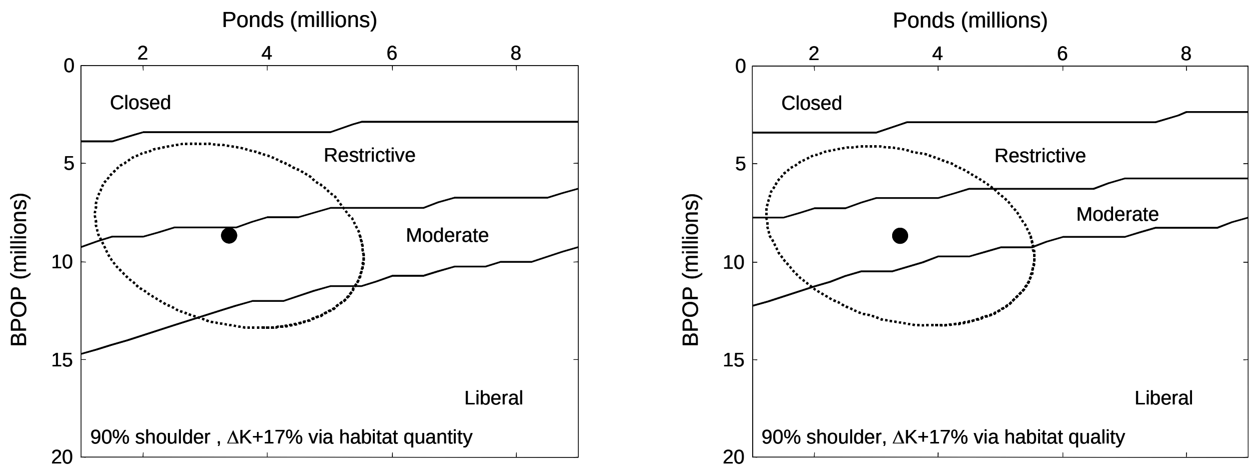

Figure 4.4. Mid-continent mallard harvest strategy, seeking 90% shoulder, with 17% increase in carrying capacity achieved through increases in (A) breeding habitat quantity (B) breeding habitat quality.

Again, while the specific results for mid-continent mallards are intriguing, the more important point is that the type mechanisms of habitat improvement (i.e., quality vs. quantity) can affect the harvest potential of the population. Coordinated modeling, assessment, and decision-making are warranted.

The effects of a shoulder strategy on duck harvest management are more complex than the previous discussion implies, because 29 species of ducks in North America are largely managed under a common set of regulations. The harvest strategies for some species (e.g., pintail, canvasback) would be influenced by adoption of a shoulder strategy for mid-continent mallards, because those harvest strategies are conditional on the mid-continent mallard season length. If a shoulder strategy for mid-continent mallards were to seek a lower shoulder than currently sought, it should reduce the need for partial seasons for these species, although the degree of that reduction had not yet been quantified. However, stock-specific shoulder strategies could be applied to other species that are managed independently of mid-continent mallards (e.g., eastern mallard, black duck, geese). In some cases, a very different shoulder point might be sought, based on species-specific considerations. For instance, a left-shoulder strategy may be appropriate for overabundant species (some geese), in order to alleviate problems associated with high abundances. We believe we have only begun to scratch the surface of how a shoulder harvest concept might be employed, but are convinced it represents a powerful framework for integrating harvest and habitat management.

Considerable work remains to fully understand the implications of a shoulder strategy and how it might be implemented. Important issues of functional form (in recruitment and survival relationships) and how the shapes of these relationships influence a shoulder strategy need to be resolved. Further, implementing this approach in AHM would motivate questions about how to track changes in carrying capacity and how to set up an AHM approach that would respond appropriately to such changes.

Reconciling harvest and habitat goals

In the narrative above, we expressed the goals of both harvest and habitat management in reference to a yield curve. For harvest management, the question is where on the right shoulder we wish to be (i.e., a fixed proportion of maximum sustainable yield to achieve a desired level of harvest) and for habitat management the question is how much we want (or are able) to expand the yield curve. We are accustomed to stating Plan goals in terms of the average breeding population size, not the yield curve. If harvest and habitat management goals are coherent, then the desired harvest shoulder point should fall on the desired yield curve at a point that corresponds to the stated breeding population size objective. If we assume that the current Plan population objectives are reasonable (i.e., 8.8M mid-continent mallards), we can ask what combinations of desired shoulder and desired yield curve result in an average population size of 8.8M. The choice of a desired shoulder point can simultaneously capture both our harvest and habitat objectives, because the combination of the harvest goal (shoulder point) with breeding population objective (8.8M) determines the habitat goal (desired yield curve).

This determination of where on the shoulder the management community wants to be involves a fundamental trade-off. For habitat management, a higher shoulder point requires greater improvement in habitat conditions. To understand this pattern, it is helpful to look at Fig. 3.5—as the carrying capacity increases and the yield curve expands, the Plan objective falls higher on the shoulder. Our current models (2006 weighted models) for mid-continent mallard dynamics suggest that 8.8 M falls at the 70.1% shoulder. This means that if we pursue a harvest rate to hold the population at that point, we could achieve an average population size of 8.8 M under current conditions, but the average harvest rate would be lower than what we have experienced in recent years. If instead we wish to have 8.8 M fall at the 85% shoulder (i.e., a greater harvest rate), the yield curve needs to be expanded from current conditions (i.e., carrying capacity must be increased) by 10.9% (Table 4.3). If we wanted 8.8M to fall at the 95% shoulder, we would need to increase carrying capacity by 25.7%; and if 8.8M was meant to fall at the peak of the yield curve (i.e., maximum sustainable harvest), we would need to increase carrying capacity by 56.6% (Table 4.3).

Table 4.3. Trade-offs between harvest potential and required habitat management in choosing a desired shoulder point on the yield curve. For each shoulder point, the increase in carrying capacity required to achieve that shoulder point at 8.8 million mid-continent mallards (the Plan goal) is shown, along with the average harvest rate that could be sustained. The harvest rate experienced depends on the method by which carrying capacity is increased (e.g., through breeding habitat quantity or quality). The results are based on the 2006 mid-continent mallard models and associated weights.

Desired Shoulder Point at 8.8 M	**Required Increase in Carrying Capacity (*K*)**	**Harvest rate at Shoulder**	
		Increase *K* through Breeding Habitat Quantity	Increase *K* through Breeding Habitat Quality
0.700	0.0 %	0.0610	0.0610
0.750	2.7 %	0.0659	0.0677
0.800	6.4 %	0.0723	0.0767
0.850	10.9 %	0.0795	0.0874
0.900	17.0 %	0.0879	0.1014
0.925	20.8 %	0.0927	0.1099
0.950	25.7 %	0.0985	0.1207
0.975	32.9 %	0.1060	0.1359
0.990	39.8 %	0.1123	0.1500
1.000	56.6 %	0.1250	*

* not calculated

On the harvest side, the desired shoulder point specifies the average harvest rate that can be sustained; as the desired shoulder increases, the average harvest rate increases (see Fig. 2.5). With the 2006 AHM models, if we desired to maintain the 70.1% shoulder, we could expect an average harvest rate of 6.1% on adult males (Table 4.3). Under these models, without a change in carrying capacity, seeking a 100% shoulder (maximum sustainable harvest) would allow an average harvest rate of 12.5%. If we consider the effect of the desired shoulder on harvest rates under changing carrying capacity (as a result of attaining Plan objectives), the results depend on the mechanism by which carrying capacity is increased. If carrying capacity is increased by changing breeding habitat *quantity* (i.e., recruitment slope) only, then higher population sizes are required to depress reproduction enough to reach equilibrium, but the intrinsic growth rate of the population remains the same. Thus, the harvest rates corresponding to particular shoulder points are the same as if the carrying capacity were not changed. However, if carrying capacity is increased by increasing breeding habitat *quality* (i.e., recruitment intercept), then the growth rate of the population at low density increases, and higher harvest rates can be achieved at corresponding shoulder points. Thus, a 95% shoulder point corresponds to a 9.9% harvest rate if *K* is increased through breeding habitat quantity, but corresponds to a 12.1% harvest rate if *K* is increase through breeding habitat quality (Table 4.3).

These dynamics reveal an important trade-off. To sustain higher harvest rates, a higher point on the yield curve is desired. But the higher we wish the Plan objective to fall on that yield curve, the bigger that yield curve needs to be, and the more we need to invest in habitat improvements, whether through increased quantity, quality, or both. This all makes intuitive sense—the more we wish to increase harvest potential, the more we need to invest in habitat improvement. So, in a sense, the trade-off here is about how much is enough. How much habitat improvement is feasible or affordable? How much harvest potential is needed to satisfy stakeholders? We can achieve an average population size of 8.8M for mid-continent mallards now, simply by decreasing average harvest rates to about 6.1%. Or, we can maintain current harvest rates and achieve an average population size of 8.8M by increasing the continental carrying capacity by about 15-20% (depending on the mechanism of habitat improvement). Where is the right balance?

If the equilibrium breeding population objectives are fixed at the levels currently specified in the Plan, then development of coherent objectives between harvest management and habitat management is a balancing act, and will require compromise from both sides. The desire for gains in harvest will have to be balanced by the reality of existing habitat conditions, and what resources will be needed to maintain or increase current continental carrying capacity. The required tradeoffs to achieve shared population objectives may be great.

But, perhaps this analysis reveals that coherence cannot be achieved with a Plan population objective of 8.8M for mid-continent mallards. The harvest goal might be to achieve at least a 90% shoulder, if not higher; the practical reality of habitat improvement might be that an increase in continental carrying capacity of 15% is the most we could hope to achieve. If so, then we cannot find a combination of harvest and habitat management goals that results in an average breeding population size of 8.8M. If this is the case, then there might be motivation for revisiting the continental population objectives outlined in the Plan.

The complexity of determining the balance between harvest and habitat goals will necessitate a deliberate and thorough dialogue within the entire waterfowl management community. The outcome should result in clear, unambiguous objectives that provide coherence, transparency, and accountability, and which motivates a joint assessment of harvest and habitat programs.

V. Acknowledging Uncertainty

In the previous sections we have presented a conceptual framework for integrating harvest and habitat management into a common analytical framework, and have explored some of the implications of our preferred approach for reconciling harvest and habitat management goals. In this section we acknowledge that there are fundamental uncertainties about waterfowl population dynamics and, thus, about how populations respond to harvest and habitat management activities. We do not believe these uncertainties in any way undermine our conceptual framework. Rather, they provide critical guidance for designing monitoring and assessment programs, prioritizing research, and for developing robust, adaptive-management strategies that can reduce uncertainty and improve long-term management performance. In recognizing the need to both acknowledge and cope with our incomplete understanding of waterfowl population dynamics, we here focus on what we believe to be the most critical sources of uncertainty for harvest and habitat managers.

The Role of Density Dependence

Changes in the size of waterfowl populations are controlled by both density-independent and density-dependent factors. Density-independent factors cause populations to increase or decrease irrespective of waterfowl abundance. Density-dependence involves a negative relationship between abundance (or more accurately, abundance per unit of limiting resource) and mortality and/or reproductive rates as a result of intra-specific competition for essential resources. The presence of density-dependence in any form and degree will determine a population's carrying capacity, the size of sustainable harvests, and the population size expected under varying levels of harvest. However, for any particular factor to exert regulating effects there must be reasonably strong density dependence in one or more of the vital rates. To the extent that the effects of density might be weak relative to other regulating or limiting factors, there are important ramifications for the efficacy of harvest or habitat management to affect population size, and for our ability to predict the consequences. Therefore, understanding the nature of density dependence in waterfowl populations is fundamental to effectively managing both harvest and habitat.

The most controversial manifestation of density dependence in waterfowl populations is the notion of compensatory hunting mortality. The compensatory mortality hypothesis posits that harvest losses can be compensated for by corresponding decreases in natural mortality. However, the hypothesis has often been cast in a form in which density dependence is only implicit (Fig. 5.1). In this formulation, annual survival rate is unaffected by increases in kill rate up to some threshold (Anderson and Burnham 1976). This conceptual model is useful for searching for evidence of compensation in band-recovery data, but it has two principal shortcomings that limit its usefulness for management: (1) the threshold kill rate at which harvest becomes additive is fixed; and (2) hunting mortality is either completely compensatory or completely additive depending only on the magnitude of the kill rate. It is extremely unlikely that populations respond to harvest in such as simplistic manner, and the lack of an underlying mechanism for compensation renders the model of no value for understanding the role of habitat in determining population size and sustainable harvest.

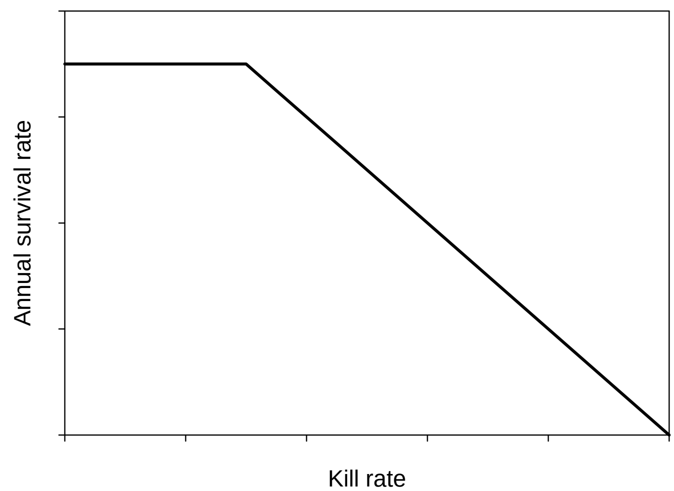

Figure 5.1. A model depicting how annual survival rate changes with changes in kill rate. Below some threshold, increases in kill rate do not result in decreases in annual survival rate; thus, hunting mortality is said to be compensatory.

We believe a more useful model concerning compensatory mortality is one in which post-harvest survival rate is a negative function of post-harvest population size (Johnson et al. 1993, Fig. 5.2). The key feature of this formulation is that it posits a biological mechanism for density dependence, allowing the amount of harvest compensation to depend on the degree of competition for resources after the hunting season. Perhaps more importantly, however, it makes explicit the linkage between the ability of populations to compensate for harvest losses and the quantity and quality of habitat, which are manifest in the intercept and slope of the relationship between post-harvest survival and waterfowl abundance. These kinds of models, which make explicit the hypotheses concerning density dependence in vital rates, are essential for linking harvest and habitat assessment and management together in a mutually reinforcing endeavor.

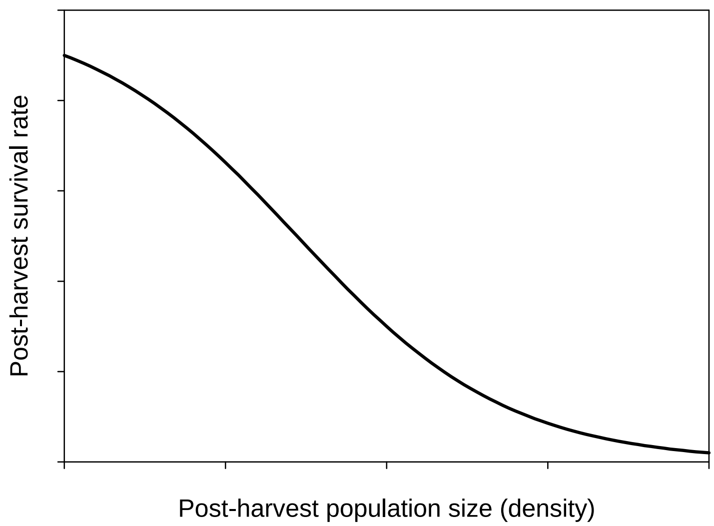

Figure 5.2. A model depicting changes in post-harvest survival rate as a function of post-harvest population size. This model posits density-dependent resource limitation after the hunting season and thus allows some compensation for losses due to hunting, especially at intermediate population sizes.

Density dependence has been difficult to investigate in waterfowl populations, and there are few explicit hypotheses about which vital rates and parts of the life cycle may be involved. Lacking sufficient demographic and environmental data at multiple scales to do otherwise, managers often have assumed a linear form of density dependence, in which a change in a demographic rate is constant across all levels of waterfowl abundance. For example, symmetric yield curves used in harvest management are a product of linear density dependence. Of course there are many reasons to believe that density dependence may be non-linear in many, if not most cases. The following examples demonstrate some of the implications of uncertainty about the form of density dependence for waterfowl managers.

Assume a population can be described by the discrete logistic equation, with intrinsic growth rate *r* and carrying capacity *K*:

$$N_{t+1} = N_t + N_t r\left(1 - \frac{N_t}{K}\right),$$

so that the change in population size is $\frac{dN}{dt} = N_t r\left(1 - \frac{N_t}{K}\right)$,

and the per capita growth rate is $\frac{dN/dt}{N} = r - \frac{r}{K}(N_t)$, which is a linear function of population size *N* (i.e., linear density dependence).

Now consider a generalized logistic model, in which an additional parameter is added to introduce non-linearity in density dependence:

$$N_{t+1} = N_t + N_t r\left(1 - \left(\frac{N_t}{K}\right)^{m-1}\right).$$

If $m = 2$ then we have the standard logistic model, but other values of m can be used to describe the how the strength of density dependence varies for population sizes less than K (Fig. 5.3). For $m > 2$, the strongest density dependence occurs near K; this might be the case for K-selected species that exhibit low variation in abundance relative to their mean (simply because even small, environmentally induced perturbations away from K induce strong density-dependent responses) (Fowler 1981). Values of $m < 2$ may be more typical of r-selected species, in which relatively large reductions in population size are necessary to invoke a strong density-dependent response.

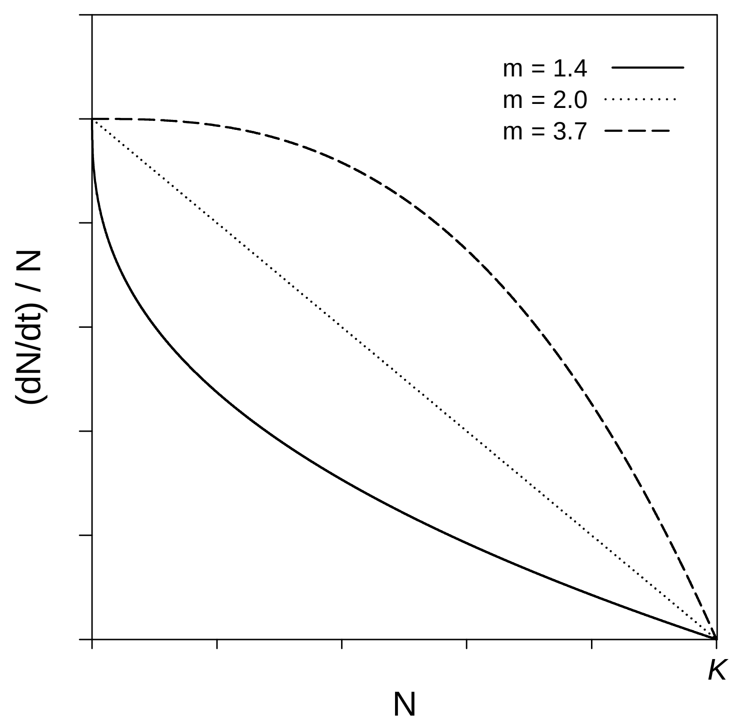

Figure 5.3. Examples of per-capita growth rate as a function of population size (N) using the generalized logistic model.

These alternative forms of density dependence have important implications for harvest management and for the congruence of harvest and Plan population objectives. For the standard logistic (i.e., $m = 2$), the population size that will maximize harvest (i.e., produce the largest surplus) is $K/2$ (Fig. 5.4), and the maximum sustainable harvest is given by $rK/4$. However, populations exhibiting $m > 2$ will have their highest net rates of increase at population sizes $> K/2$ (specifically, $Km^{\left(\frac{-1}{m-1}\right)}$), with maximum sustainable harvest given by $r\left(1-\frac{1}{m}\right)Km^{\left(\frac{-1}{m-1}\right)}$, which is higher than for the standard logistic. In contrast, populations with $m < 2$ will exhibit their greatest productivity at population sizes $< K/2$, and will have a lower maximum sustainable harvest than the standard logistic. Therefore, the form of density dependence is critical in evaluating the population size necessary to maximize harvest (or to attain some fixed proportion of he maximum harvest), and for determining to what extent that population size differs from the Plan population objective. Moreover, we emphasize that quantification of the tradeoff between the desired proportion of the maximum harvest and the increase in *K* necessary to support that harvest at the Plan population objective is dependent on assumptions concerning the functional form of density dependence.

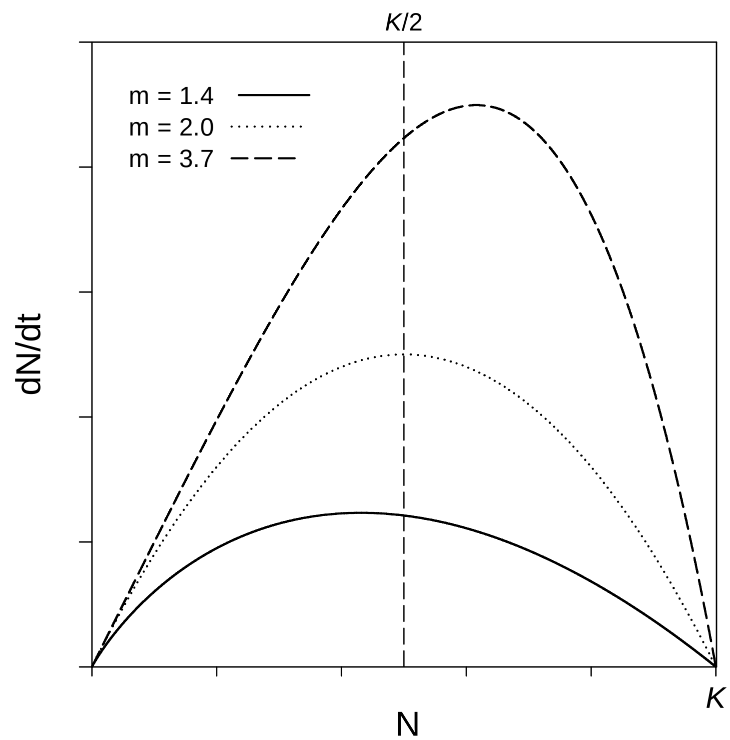

Figure 5.4. Examples of net population growth as a function of population size (N) in the generalized logistic model.

System Change

Another type of uncertainty involves unexpected changes in the dynamics of the managed system. If the variation in environmental factors affecting vital rates is random (i.e., with constant mean), then systems will tend toward some (stochastic) equilibrium as long as harvests are sustainable. An example is precipitation in the northern Great Plains of the U.S., which exhibits great annual variation, but little in the way of long-term trend (Fig. 5.5). In these cases, changes in *K* and harvest potential are short term and random, and managers can largely focus on average environmental conditions for planning and evaluation purposes.

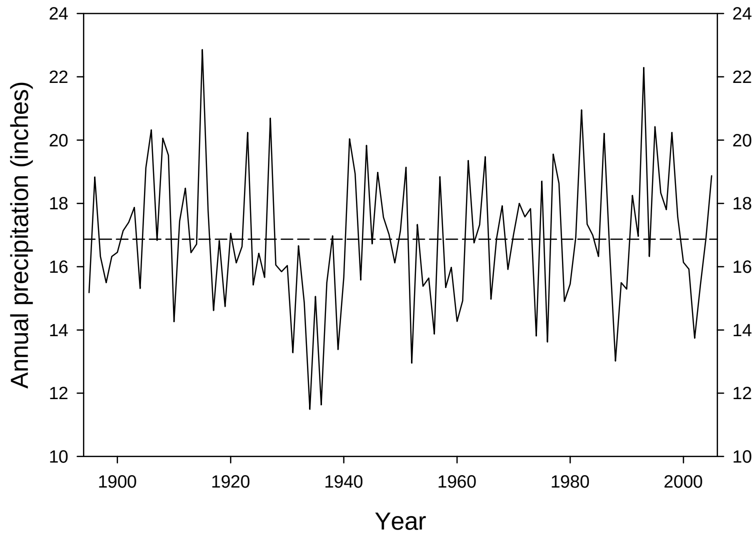

Figure 5.5. Annual precipitation in the northern Great Plains of the U.S. (Montana, North Dakota, South Dakota, Wyoming, and Nebraska).

A more difficult type of system change with which to cope involves long-term trends in key environmental drivers of population dynamics. There is growing evidence in natural resource management that this type of environmental change may be more common than usually assumed, and it can go unrecognized until essentially irreversible system changes have taken place. An example of long-term system change appears to be occurring with black ducks and is manifest as a long-term decline in recruitment (Conroy et al. 2002). The cause for the decline is unknown, but may be related to declines in the quantity and/or quality of breeding habitat, wintering habitat, or both. Whatever the cause, the management implications are profound, suggesting that carrying capacity and maximum sustainable harvest of black ducks have decreased by 35% and 60%, respectively, in the past two decades (Fig. 5.6). The ability of an adaptive process to track these changes depends on both the magnitude and frequency of such changes. If the changes in underlying population dynamics are too large or frequent, learning becomes essentially impossible because of limitations imposed by the precision of extant monitoring programs, and because of the role of past experience in the updating of model weights. Therefore, it seems imperative that managers develop better ways to monitor and assess large-scale changes in system dynamics, and to develop management programs that can account for or reverse those changes.

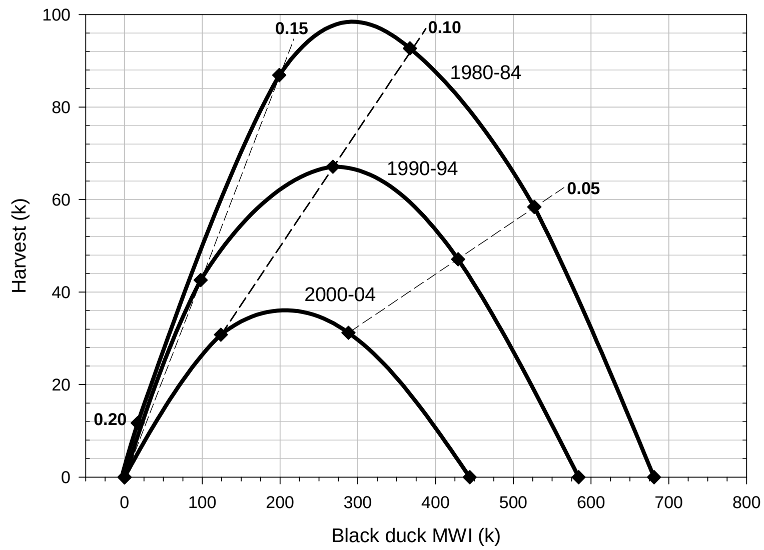

Figure 5.6. Estimated collapses in the yield curve of black ducks as a result of declining recruitment. Diagonal lines represent the indicated harvest rates on each curve.

Effects of land management

The model sets that currently are used for AHM, and which were used to generate the figures in the previous sections of this report, focus on uncertainty in the effects of harvest on population dynamics, but a fully unified modeling framework will also have to address uncertainty in the effects of habitat management on population dynamics. In a sense, such effects are a subset of the "system change" effects discussed in the previous section, but they warrant special attention because the efforts of the Plan are deliberate attempts at system change. Three issues deserve special attention in articulating uncertainty about the effects of habitat management on waterfowl populations: (1) the effects of habitat management on mean demographic rates; (2) the effects of habitat management on temporal variation in demographic rates; and (3) the connection between local and continental demographic effects.

What are the effects of habitat management, as carried out by the joint ventures, on demographic rates? Can we develop recruitment and survival models that reflect alternative hypotheses about how landscape conditions (e.g., wetland density, extent of perennial cover on breeding areas) affect vital rates? Can we go farther and develop models that accommodate external factors as predictors? There is considerable uncertainty about these dynamics, but a unified modeling framework would allow a clearer articulation of these uncertainties and would pave the way for development of effective adaptive management strategies.

Beyond the effect of land management on mean demographic rates, there is also uncertainty about how management affects the variation in those rates over time. Many waterfowl species live in, and are adapted to, highly variable systems. What features of the landscape moderate or exacerbate the effects of that variation? Can certain habitat management actions remove the adverse effects of the dry years, or enhance the positive effects of the wet years? In the prairies, managers often speak of "setting the table", that is, having a landscape configuration that allows recruitment to be extremely high when favorable water conditions occur. This intent can be captured in formal models that predict how waterfowl populations respond to varying environmental conditions. Articulation of such models, and the uncertainty surrounding them, should lead to a better understanding of what management actions are expected to be most beneficial, as well as identify opportunities to reduce uncertainty through adaptive management.

Finally, it's clear that one of the greatest challenges in making predictions about the effect of Plan activities on continental waterfowl populations is connecting local habitat management actions with continental demographic effects. This involves a better understanding of the spatial dynamics of these populations, including where and when in the annual cycle limitation and regulation act most strongly. Within a period of the annual cycle (say, breeding), how do local habitat changes, and their associated demographic effects, combine to produce demographic effects at larger spatial scale and longer time scales? Between periods of the annual cycle, how do demographic effects (say, in the winter), carry-over to demographic effects in the subsequent breeding season? We need alternative models that capture the uncertainty about these spatial and temporal dynamics, not only to provide predictive ability, but to permit improved management as learning accrues.

We recognize that development of such models, and the associated articulation of key uncertainties, appears daunting. But the benefits of integrated decision-making and joint monitoring and assessment depend on having a unified modeling framework that is explicit about what we know and what we don't know. An appendix to this report provides some additional thoughts on how development of such a modeling framework might proceed.

VI. Explicit Incorporation of Human Dimensions into the Unified Harvest-Habitat Framework

Once, when the business of wildlife management was rooted almost exclusively in the production and consumption of single, valued species for sport and recreation, agencies needed to answer to a relatively narrow range of stakeholders, largely ignored uncertainty, and operated in command-and-control style fashion, (Lancia et al. 1996, Holling and Meffe 1996). Now, managers and policy makers must respond to broader, frequently better-informed, organized, and sophisticated constituencies, demanding transparency and accountability in management decision-making. People and political processes are central features of waterfowl and wetland management, and adaptive management requires active participation by those most affected by the policies, in this case waterfowl hunters (Shindler & Cheek, 1999).

Waterfowl harvest management has, of course, made significant strides in 'single-loop' institutional learning (Figure 6.1.) by adopting adaptive management. However, to deal better with the modern society, we must invest in enhanced use of adaptive management, for habitat and harvest programs, as well as decision analysis to explicitly integrate stakeholder values. Presently, the absence of explicit linkages for stakeholder input to decisions regarding habitat and harvest management means that the technical side (research and management), whether explicitly adaptive (as in the case of harvest) or not (as in the case of habitat) is divorced from the policy/administration side (Figure 6.1).

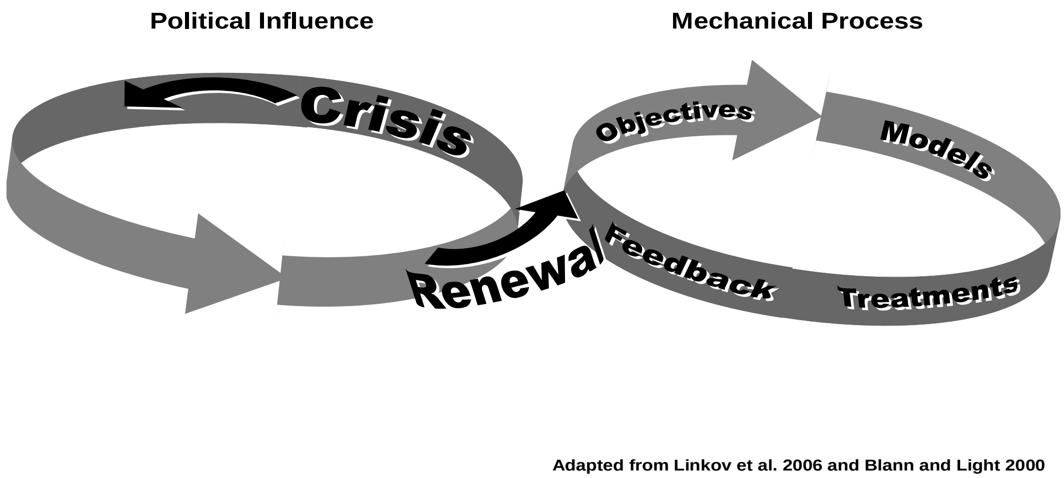

Figure 6.1. Single -Loop Institutional Learning; Adaptive management is disconnected from active stakeholder involvement

The primary limitation to integrating harvest and habitat management with stakeholder interests, however, has not been technical. Agreement on the objectives and how information will be used in decision-making has been lacking; thus, technical strides often have been disconnected from the policy or management decisions. Differences in values among stakeholders, based on different perceptions about the relative importance of factors that affect the dynamics of natural populations – among which harvest is only one – can lead to conflict or even management paralysis. Natural and social systems are dynamic, and constant attention to changing ecological and social conditions will require purposeful integration of policy review in the context of technical advances (i.e., "double loop learning" – Figure 6.2.). This will require serious dialogue about policy and management objectives, a willingness to engage a broader range of stakeholders and their diverse interests, and avoiding retreating into a traditional "command and control" culture.

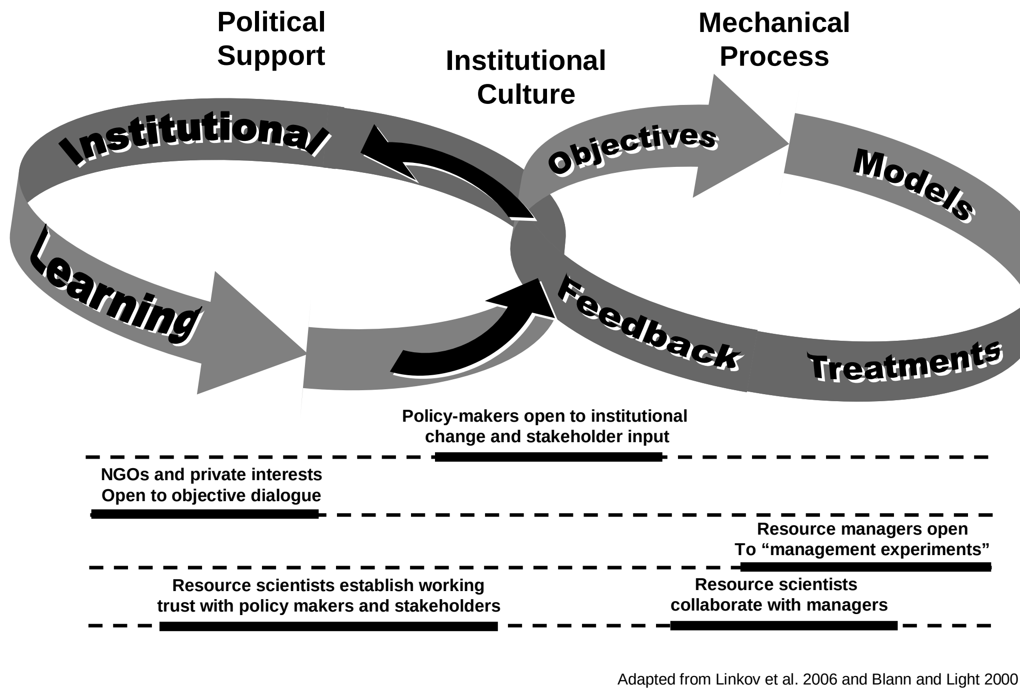

Figure 6.2. Adaptive management integrated within an institutional culture open to stakeholder involvement and structured learning

In developing and formalizing this double-loop feedback mechanism, a number of issues will need to be considered by the waterfowl management community. Efforts by the Waterfowl Hunter Satisfaction Think Tank (Case, 2004) provided valuable insights into the relationship between waterfowl hunting regulations and hunter satisfaction, recruitment, retention and their involvement and support for conservation programs. We reiterate here the need to more explicitly clarify this relationship and the linkage between the human dimension component and the elements of harvest management and habitat conservation (Figure 6.3). By developing a better understanding of what motivates people to hunt and to be engaged in the support and delivery of conservation programs, the management community will be better positioned to define the role that hunters may play in achieving the shared objectives for harvest and habitat management.

In addition, a variety of processes are used by the states to engage their publics in decision-making, and there is no clear mechanism for incorporating stakeholder input into the process at a national scale. Also, the effectiveness of such actions and their role in achieving broader scale objectives is difficult at best because of a lack of useable metrics that can be collected across jurisdictions to help inform policy decisions. Stakeholder input should not be limited to hunters. While the involvement of the hunting public in support of landscape level conservation and the broader ecological benefits that are produced is necessary, the role of non-hunting segments of society, including (and perhaps most importantly) landowners, may be instrumental in shaping whether hunting and hunters are valued in the long term.

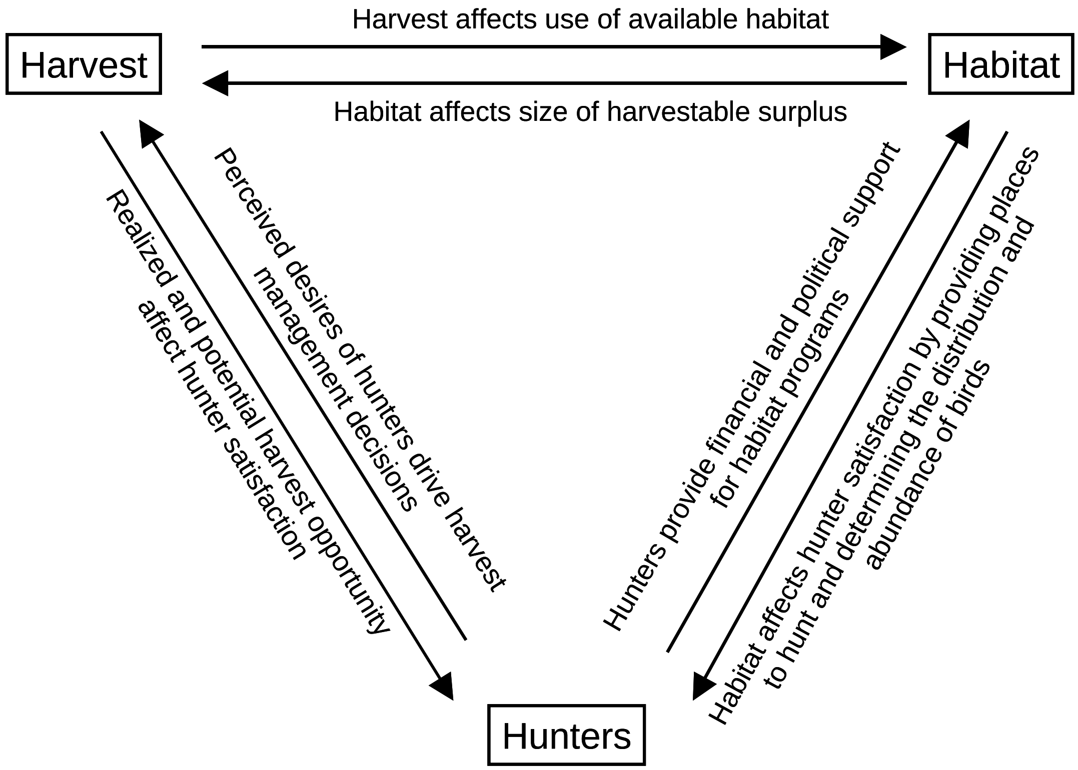

Figure 6.3 The relationship between harvest, habitat and hunters in North American waterfowl management.

Conclusions and recommendations advanced by the Think Tank report represent important elements for future consideration by the management community as they seek to more systematically gather information to help guide regulatory decisions. These include the following:

- The preferences of hunters are dynamic, may change over time, may differ by stage of development and are likely influenced by resource condition.
- Satisfaction is only one component affecting participation decisions and long-term recruitment retention rates are less likely tied to regulations and more significantly influenced by social and cultural values.
- The composition of hunters, as documented by license purchase, may vary considerably between years and there is mounting evidence that a large pool of potentially active hunters does exist.
- Considerable foundational research would be required to develop hunter-related performance metrics and a more explicit process for how those metrics would be used to influence management decisions. Monitoring and evaluation criteria would be essential.
- States should consider a variety of methods to solicit and incorporate stakeholder input to ensure broader representation in the decision making process.

- Hunting may contribute to natural resource stewardship and ethics but that behavior pattern is not universally expressed among the hunting community.
- Stewardship attitudes and knowledge cannot be regulated but may be hypothetically reinforced in appropriate fashion by regulations or by the regulation-setting process.

Ultimately, addressing the balance between management actions affecting habitat and harvest also will require a forum within which uncertainties about stakeholders (including hunters, landowners, etc.) are addressed. We acknowledge that a focus on the human dimensions elements will occur at a pace slower than advances linking harvest and habitat. The institutional infrastructure, expertise, and monitoring tools have been developed in only a rudimentary manner. Yet, this historic source of contentiousness and uncertainty will remain as a key uncertainty until it can be actively integrated into waterfowl conservation strategies.

VII. Recommendations

A "Gap Analysis" of Management Capacity

The waterfowl community already has strength in technical capacity and policy frameworks for waterfowl management decisions (Table 7.1), but these are centered mostly in separate harvest and habitat management "silos". We believe that there is an important need to develop the institutional structures and linkages to accomplish a basic unification of waterfowl management.

Table 7.1. Current capacities and future challenges for waterfowl management

Demonstrated Capacity	Challenges Remaining
To plan and deliver habitat conservation through various agencies and NGOs, coordinated by Joint Ventures and overseen by the international Plan Committee.	Limited ability at present to evaluate the effects of local and regional conservation actions on waterfowl vital rates and breeding population size. This ability varies greatly among Joint Ventures. Limited understanding of what major limiting factors are for most populations and where they occur. Little explicit consideration of the costs of one action over another (e.g., increasing survival or recruitment rates) to achieve population objectives. Limited ability to translate regional habitat change to any change in continental carrying capacity (K). The regional limitations noted above are compounded by no extant framework for "scaling up" regional effects to the continental scale of Plan population objectives. Few forma linkages among JVs that share populations. No elements of what waterfowl habitat managers actually do are incorporated in current models of system dynamics used in adaptive harvest management. There is no clear and agreed upon demographic interpret-tation of Plan population objectives, including specified

	contexts of environmental variation and harvest policy.
To manage the sport harvest of waterfowl through the 4 Flyway Councils (U.S.) or through federal/provincial cooperation (Canada). In the U.S., oversight is provided by the National Flyway Council and the Service Regulations Committee.	Differences in the formal management framework between Canada and the United States. Current models of system dynamics used in AHM do not incorporate recent advances in understanding of habitat factors affecting waterfowl recruitment. No clear strategy for adapting harvest policy to significant long-term changes in carrying capacity. Important uncertainty about the strength and functional forms of density dependence in exploited waterfowl populations. Nascent ability to manage harvests of shared stocks among multiple jurisdictions (e.g., western, mid-continent, and eastern mallards; black ducks in Canada and the U.S.) with differing management objectives and harvest frameworks.
To develop this proposed theoretical framework for integrating habitat and harvest management	No existing technical body with expertise in both habitat science (e.g., the NSST) and harvest science (e.g., the AHM Working Group) to carry on the technical work begun by the JTG. No single management forum exists for integrating policy options across habitat and harvest dimensions and across national boundaries. Policy-level leadership to promote such integration has not been developed.
Some survey information has been assembled on elements of hunter satisfaction. The AFWA has demonstrated leadership in the exploring human dimensions of waterfowling.	There is limited understanding of hunter satisfaction related to harvest or habitat objectives. There is limited understanding of landowner and other stakeholder motivations related to hunting or habitat conservation objectives. No theoretical framework is developed for linking human dimensions to integrated harvest and habitat conservation objectives. Uncertainty about whether explicit human dimensions objectives should be developed or simply expressed in the setting of population and harvest objectives. No policy forum exists for consideration/ adoption of human dimension factors in harvest and habitat objectives and policies.

Considering the multiple challenges remaining to integration of the main components of waterfowl management (Table 7.1) it is clear that the waterfowl community needs to:

- Develop the institutional means and resources to pursue joint technical matters that integrate harvest and habitat management and reduce key uncertainties in both management dimensions.

- Develop the institutional means to pursue policy-level integration of harvest and habitat conservation objectives.

- Develop the capacity for harvest and habitat policy decisions that include considerations of human dimensions.

- Develop the capacity for research and ongoing technical support of human dimension matters, particularly as they affect setting of harvest and habitat objectives.

With these existing capacities and incremental needs in mind, we offer the following specific recommendations to the waterfowl management community:

<u>Joint Task Group Recommendations</u>

The waterfowl management community should commit to developing and adopting a coherent management framework with common, linked population objectives. In order to accomplish this, the following steps should occur:

1. The U.S. Fish and Wildlife Service (FWS) and the Canadian Wildlife Service (CWS), in concert with the Flyway Councils, should seek methods to more formally link harvest and habitat objectives. Specifically, management authorities should adopt a "shoulder strategy" for northern pintails and mid-continent mallards. The principles of coherence and integration should be central components of the revised U.S. federal EIS on waterfowl harvest,

2. The Plan Committee should adopt the same "shoulder strategy" as a more precise interpretation of Plan population goals in the presence of harvest and environmental variation. This will help accomplish coherence between harvest policy and habitat objectives, and focus the attention of the joint ventures on conservation actions designed explicitly to enhance continental carrying capacity (K). The principles of coherence and integration should be central components of the 2009 Update of the Plan, which should consider a first comprehensive revision of Plan population objectives since 1986.

3. The federal wildlife services, together with interested partners, must commit to enhancing essential technical capacity for the Plan's Science Support Team (NSST) and the Adaptive Harvest Management Working Group (AHMWG) that will play key roles in the technical integration of waterfowl management. One pressing need is to develop population models and assessment processes that encompass the main elements and sources of uncertainty for both harvest and

habitat managers.

4. We urge that the waterfowl community focus more scientific efforts on reducing the key ecological uncertainties surrounding current models of population dynamics (e.g., density dependence) and the relationships between waterfowl vital rates, carrying capacity (K), and landscape properties that habitat managers strive to manipulate. Researchers should strive to create shared monitoring and assessment programs that help inform both harvest and habitat management decisions.

5. The FWS and CWS directorates should convene a waterfowl management policy summit in the near future to address the institutional needs and policy decisions necessary to implement a framework for habitat and harvest management integration.

6. A new Human Dimensions Working Group (HDWG) should be convened to advance the assessment of waterfowl stakeholder values and approaches for more explicitly incorporating this information in management decisions.

First Steps

Implementing these recommendations will require communication and coordination among diverse internal and external stakeholders, completion of new technical assessments for habitat and harvest management, the addition of technical capacity in the area of human dimensions, and leadership from agencies with mandated responsibilities for waterfowl management.

In the short term (i.e., within 6 months after completion of this report) we urge that waterfowl management stakeholders complete their review of our report and develop consensus about acting on the 6 recommendations listed above.

We think that the single most useful step that could be taken in 2007 would be for the Directors of the FWS and CWS, in collaboration with AFWA, the Plan Committee, and the NFC, to convene a waterfowl management policy summit where implementation of the specific policy and technical recommendations in this JTG report might be debated, refined and acted upon. Creative solutions are needed and the entire waterfowl community should be challenged to contribute novel ideas for solutions at the summit. Other foundational elements for review at the summit should include the papers emerging from the harvest management workshop held at the North American Wildlife and Natural Resources Conference in March 2006, and the conclusions and recommendations from the just-concluded Plan Assessment.

Building the institutional capacity to set waterfowl management on a coherent course might occur in a number of ways. We offer the following two suggestions as a starting point for further discussions at the summit.

The Association of Fish and Wildlife Agencies, including their Canadian members, perhaps in conjunction with the National Flyway Council, could take the lead in convening a new Human Dimensions Working Group (HDWG). This HDWG should be given specific short-term objectives to accomplish but might evolve into a body providing ongoing technical capacity for analyses of human dimensions in waterfowl management. In the short run, elucidation of what duck hunters and non-consumptive waterfowl enthusiasts want will be critical for a comprehensive review of waterfowl population objectives.

Because no policy-level forum presently exists that integrates harvest management and habitat management across international borders, and because further dialog on population objectives is urgent, the federal wildlife services should consider convening a time-limited policy-level waterfowl management integration committee as an oversight group that would receive stakeholder input and facilitate social choices about population goals in a participatory framework that integrates interests from harvest, habitat, and social perspectives. Presumably, such an integration committee would need to ensure effective linkages with the federal wildlife agencies, the SRC, the Plan Committee, and the Flyway Councils. Regardless of how such a group is constituted, some new means ensuring effective dialog across management disciplines seems essential.

Waterfowl management in North America has been one of the largest and most successful enterprises in the world of wildlife management, but as we have argued in this report, it can and must be improved to deal with the challenges posed by ongoing habitat loss, new conservation opportunities, changing stakeholders, and evolving knowledge of system dynamics. We have a great foundation to build upon; our challenge is to create coherence and a common vision as we work together to sustain waterfowl populations and our wildfowling heritage for future generations.

Appendix. Preliminary Thoughts on a Modeling Framework for Connecting Habitat Conservation to Waterfowl Population Dynamics

A fundamental challenge to substantive integration of harvest and habitat management remains – there is very little relevance in the current AHM model set to what habitat managers do on the land. For example, the only environmental variable explicitly incorporated in the AHM models is the number of May ponds in Canada, and these are used only as indices of uncontrolled environmental variation. Habitat managers, however, focus on protecting or enhancing wetland and upland habitats in ways that supposedly affect waterfowl vital rates. Accordingly, habitat managers are interested in comparing recruitment or survival models that reflect alternative hypotheses about how landscape conditions (e.g., wetland density, extent of perennial cover on breeding areas) affect vital rates. We suspect that the path to truly integrated decision-making, and shared monitoring and assessment systems, will be through demographic models linked at multiple spatial scales that better integrate key uncertainties in both harvest and habitat management.

<u>Linking regional management actions to change in continental-scale demography</u>

Changes in continental carrying capacity are assumed to be affected by changes in the recruitment and survival rates of whole populations. This is because we have inferred the dynamics of these populations from annual changes in demographics (population size, survival rates, age ratios, etc.) estimated at continental scales. Unfortunately, we understand very little about how changes in *regional* vital rates (e.g., nest success in the PPR or over-winter survival in the Mississippi Valley) affect continental population dynamics. To make better-informed decisions about conservation investments we must improve our insights about these relationships.

Exploring frameworks for accomplishing this is beyond the scope of this report; however, we suggest that development of simplistic multi-scale demographic models that reflect the major hypotheses about the main ecological drivers of duck populations might be a productive way to begin. Clearly a simple mental model was used by the Plan authors 25 years ago as they contemplated the complementarity of work in key geographic regions throughout the annual cycle. We envision such a model as a means to enable scenario playing and sensitivity analyses that might reveal insights such as what scale of change in over-winter survival would be required to offset a given loss in recruitment potential. The results of a suite of such simulations, posing different questions, should provide managers with at least some sense of priority for investment strategies. Such a model could also help develop future monitoring programs that reduce uncertainty about the major sources of variation in species-specific population dynamics.

One approach might be to create linked regional models of population dynamics that reflect current thinking about the drivers and sources of variation in waterfowl recruitment and survival. A simple conceptual framework might be developed as follows. Consider first a breeding area (e.g., a waterfowl conservation region or joint venture). The quantity and quality of different habitats (A to D) affect the slopes and intercepts of the recruitment and mortality functions (Fig. A.1). The summation of these processes yields a population of birds (surviving adults and new recruits) leaving this region that contribute to the fall population (the “fall flight”). Actions of habitat managers within the region ultimately determine the quantity and quality of habitats available and in so doing, affect the slopes and intercepts of the vital rate functions. The challenge to managers is to determine *by how much* their habitat efforts effect changes in these vital rates.

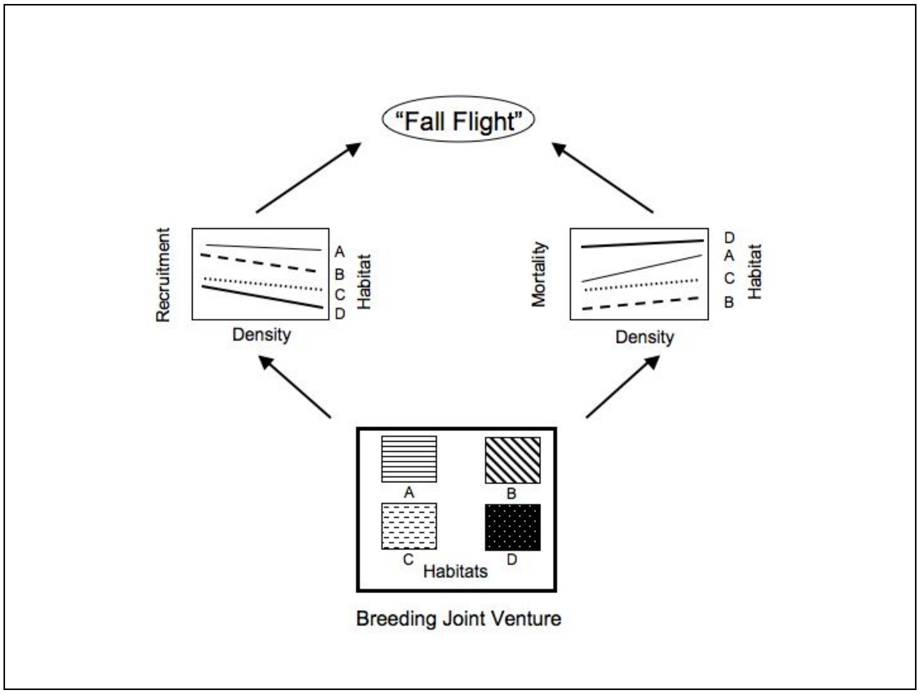

Figure A.1. A schematic illustration of habitat-specific vital rate functions on a breeding ground Joint Venture. The mosaic of habitats present in the region is illustrated simply as habitats A to D. The quantity and quality of these habitats affects the slopes and intercepts of the recruitment and mortality functions.

Similarly, a parallel structure could be constructed for a non-breeding region (Fig. A.2). Again, the quantity and quality of habitats in the region determine the slopes and intercepts of the vital rate functions. A critical distinction is that mortality, rather than recruitment, is likely to be the vital rate most influenced by non-breeding habitat. The mortality rate may vary directly with habitat availability or indirectly via the effect of habitat on body condition. It is also plausible (although rarely demonstrated) that body condition further influence survival or recruitment on the breeding grounds the following spring (Heitmeyer 1988, Kaminski and Gluesing 1987), although we have not incorporated such cross-seasonal linkages here.

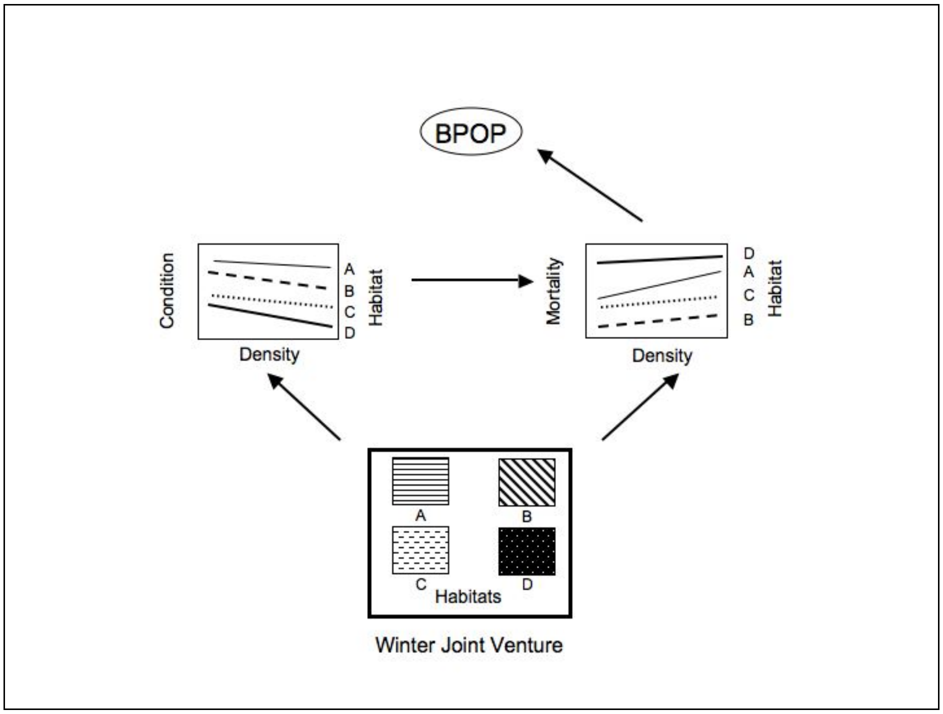

Figure A.2. A schematic illustration of habitat-specific vital rate functions on a wintering ground Joint Venture. The quantity and quality of habitats (A to D) affects the slopes and intercepts of the recruitment and mortality functions.

To scale up from regional to continental scales requires that the biological models developed for individual regions are coalesced at a continental scale. Figure A.3 illustrates a very simplified version depicting two breeding and two wintering regions. Hence, the fall population represents the summation of all birds produced via habitat efforts within individual breeding regions, in turn influenced by the habitat-specific effects on recruitment and mortality. These birds are then distributed among the winter regions wherein mortality is determined by habitat availability and quality within regions, and by harvest policy and its influence on harvest rates. The birds leaving the winter grounds in spring comprise the breeding population, which is dispersed once again among the breeding regions. A realistic model would also need to account for movement of birds among and within breeding and winter regions.

Even this admittedly simple conceptual framework may be seen as unreasonably complex and we fully recognize the enormous challenge to parameterize such a model. However, the objective here is not to develop a complex model, but rather one that captures the essential dynamics of the population as simply as possible. Also, we believe it is not necessary to have empirical estimates of all of the parameters or functional relationships included in the model for it to be useful. A mixture of empirical estimates and plausible ranges of values from expert opinions would be sufficient to make the exploration of model predictions and sensitivities informative. Such a framework could serve as a useful heuristic to focus attention on the key underlying assumptions upon which we base our management plans. Whether or not we can fully quantify the relationships between habitat and vital rates, we currently manage with the implicit assumption that such relationships exist. Moreover, even such simple models may prove useful as “rapid prototypes” to examine the potential influence, or sensitivity, of the functional relationships of habitat to key vital rates in each region (Delgado et al. 1997, Schellinck and White 2005). Some efforts have already been made in this regard. For example, the Adaptive Management Assessment Team (AMAT) developed a conceptual model that linked breeding, migration, and wintering areas through survival and recruitment rates and transition probabilities (R. Johnson, pers. com.). We believe that further efforts to develop this framework would be worthwhile.

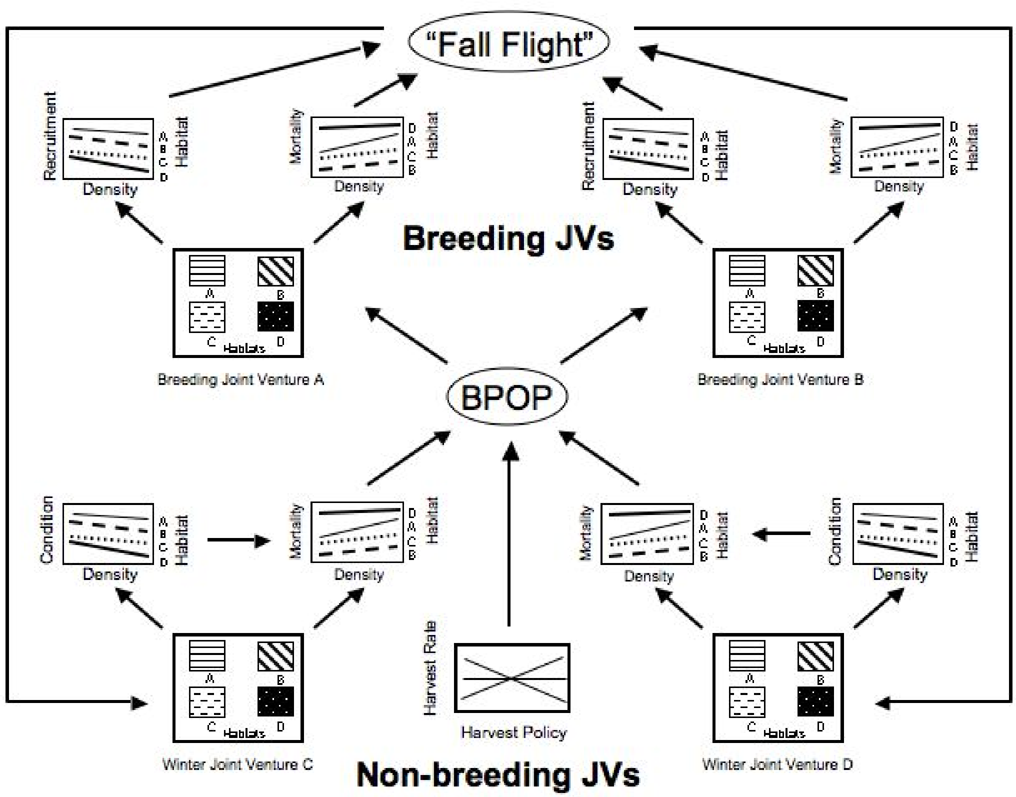

Figure A.3. A schematic illustration of the influence of linkages between breeding grounds, wintering areas, and harvest policy on continental waterfowl populations.

We think that the Plan Science Support Team (NSST), comprised as it is of scientists and technicians with both national and joint venture perspectives, is the logical coordinating body for the further development of these ideas and models. There seem to be two general ways of advancing such dicussions: (1) asking if the current joint venture goals “add up” to a sufficient continental population with plausible demographic linkages, or (2) whether there is a more open-ended approach of considering what demographic changes are needed, in what regions, to achieve a given continental population objective.

Reducing uncertainty about the effects of regional conservation actions on waterfowl population vital rates and continental-scale carrying capacity.

The draft report of the Plan Assessment Steering Committee recommends improvement in our understanding of the effects landscape variation and management actions on waterfowl vital rates. Most joint ventures continue to base their objectives on abundances of birds, not through effecting changes in vital rates (at least, not explicitly). To move more effectively in this direction, joint ventures will need to address this shortcoming. Our exploration of the relationship between harvest and habitat management and considerations of how habitat conservation actions might affect carrying capacity and thus harvest potential, has made clear that any conservation investment strategy ought to be informed by the best available estimates (or at least by explicit testable assumptions) of the effects of habitat change on vital rates. Even if the formal aggregation of joint venture effects to larger spatial scales remains problematic, greater certainty around the effects of management actions on regional vital rates can provide a strong basis for regional investment decisions. Such studies have already substantially altered the program direction of some joint ventures, the Prairie Habitat Joint Venture being a good example.

The challenge of relating management actions to population impacts is greater for non-breeding areas, but we encourage those joint ventures to explore collectively whether greater insights into at least the effects of habitat variation on vital rates might be attainable. We believe that progress with such integrated demographic models will prove essential for the operational unification of waterfowl management.

Literature Cited:

Anderson, D. R., and K. P. Burnham. 1976. Population ecology of the mallard. IV. The effect of exploitation on survival. Fish and Wildlife Service Resource Publication 128. U.S. Department of the Interior, Washington, D.C.

Calverley, B.K., and D. A. Boag. 1977. Reproductive potential in parkland- and arctic-nesting populations of mallards and pintails (Anatidae). Canadian Journal of Zoology 55(8):1242-1251

Case, D.J. (ed.). 2004. Waterfowl hunter satisfaction think tank: understanding the relationship between waterfowl hunting regulations and hunter satisfaction/participation, with recommendations for improvements to agency management and conservation programs. A final report to the Wildlife Management Institute for U.S. Fish and Wildlife Service Multi-state Conservation Grant #DC M-15-P. D.J. Case & Associates, Mishawaka, IN.

Conroy, M. J., M. W. Miller, and J. E. Hines. 2002. Identification and synthetic modeling of factors affecting American black duck populations. Wildlife Monograph No. 150. 64pp.

Delgado, M. Gomez-Skarmeta, A.F. Martin, F. 1997. A fuzzy clustering-based rapid prototyping for fuzzy rule-based modeling. IEEE Transactions on Fuzzy Systems 5: 223-233.

Derksen, D. V., and W. D. Eldridge. 1980. Drought-displacement of pintails to the Arctic coast plain, Alaska. Journal of Wildlife Management 44:224229.

Dzubin, A. 1969. Comments on carrying capacity of small ponds for ducks and possible effects of density on mallard production. Pages 138-160 in Saskatoon wetlands seminar. Canadian Wildlife Service Report Series 6.

Fowler, C. W. 1981. Density dependence as related to life history strategy. Ecology 62:602-610.

Grieb, J. 1985. North American Waterfowl Management Plan: the U.S. Plan. Proceedings of the Fifth International Waterfowl Symposium, Kansas City, Missouri.

Heitmeyer. M. E. 1988. Body composition of female mallards in winter in relation to annual cycle events. Condor 90: 669-680.

Hilborn, R., C. J. Walters, and D. Ludwig. 1995. Sustainable exploitation of renewable resources. Annual Review of Ecology and Systematics 26:45-67.

Holling, C. S., and G. K. Meffe. 1996. On command-and-control, and the pathology of natural resource management. Conservation Biology 10: 328-337.

Jamieson, L. E. and Brooks, S. P. 2004. Density dependence in North American ducks. Animal Biodiversity and Conservation, 27: 113–128.

Johnson, F. A., B. K. Williams, J. D. Nichols, J. E. Hines, W. E. Kendall, G. W. Smith, and D. F. Caithamer. 1993. Developing an adaptive management strategy for harvesting waterfowl in North America. Transactions of the North American Wildlife and Natural Resources Conference 58:565-583.

Johnson, F. A., W. L. Kendall, and J. A. Dubovsky. 2002. Conditions and limitations on learning in the adaptive management of mallard harvests. Wildlife Society Bulletin 30:176-185.

Johnson, R. R., U.S. Fish and Wildlife Service, personal communication.

Kaminski, R.M. and E. A. Gluesing. 1987. Density- and habitat-related recruitment in mallards. Journal of Wildlife Management 51: 141-148.

Lancia, R.A., C.E. Braun, M.W. Collopy, R.D. Dueser, J.G. Kie, G.J. Martinka, J.D., Nichols, T.D. Nudds, W.R. Porath, and N.G. Tilghman. 1996. ARM! for the future: adaptive resource management in the wildlife profession. Wildlife Society Bulletin. 24: 436-442.

Nichols, J.D. and J. E. Hines. 1987. Population ecology of the mallard VIII. Winter distribution patterns and survival rates of winter-banded mallards. U. S. Fish and Wildlife Service Resource Publication 162.

Punt, A. E., and A. D. M. Smith. 2001. The gospel of maximum sustainable yield in fisheries management: birth, crucifixion and reincarnation. Pages 41-66 *in* J. D. Reynolds, G. M. Mace, K. H. Redford, and J. G. Robinson, editors. Conservation of exploited species. Cambridge University Press,Cambridge, UK.

Reinecke, K. J., C. W. Shaiffer, and D. Delnicki. 1987. Winter survival of female mallards in the Lower Mississippi Valley. Transactions of the North American Wildlife and Natural Resources Conference 52:258-263.

Reynolds, R. E., T. L. Shaffer, R. W. Renner, W. E. Newton, and B. D. J. Batt. 2001. Impact of the Conservation Reserve Program on duck recruitment in the U.S. Prairie Pothole Region. Journal of Wildlife Management 65:765-780.

Ringelman, J. K. (ed.). 2005. Prairie Pothole Joint Venture Implementation Plan. Section II — Waterfowl Plan. Prairie Pothole Joint Venture, Denver, CO. 33pp.

Ryan, M. R., L. W. Burger, and E. W. Kurzejeski. 1998. The impact of CRP on avian wildlife: A review. Journal of Production Agriculture 11:61-66.

Schellinck, J. and T.White. 2005.Use of Netlogo as a rapid prototyping tool for the creation of more rigorous spatially explicit individual-based biological models. First Open International Conference on Modeling & Simulation.

Shindler, B. and K. A. Cheek. 1999. Integrating citizens in adaptive management: A propositional analysis. Conservation Ecology 3:9.

Tori, G. M., S. McLeod, K. McKnight, T. Moorman, and F. A. Reid. 2002. Wetland conservation and Ducks Unlimited: Real world approaches to multispecies management. Waterbirds 25:115-121.

U.S. Department of the Interior and Environment Canada. 1986. North American Waterfowl Management Plan. U.S. Department of the Interior, Washington, D.C., USA.

Vickery, W.L. and T. D. Nudds. 1984. Detection of density-dependent effects in annual duck censuses. Ecology 65: 96-104.

Viljugrein, H., N. Chr Stenseth, G. W. Smith and G.H. Steinbakk. 2005. Density dependence in North American ducks. Ecology 86: 245-254.

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