AMERICAN BLACK DUCK ADAPTIVE MANAGEMENT –PRELIMINARY INTEGRATED HABITAT AND POPULATION DYNAMICS FRAMEWORK

A Case Study from the Structured Decision Making Workshop
September 13—17, 2010
National Conservation Training Center, Shepherdstown, WV, USA

Patrick K. Devers, Conor McGowen, Brady Mattson, Rod Brook, Min Huang, Tim Jones, Dan McAuley, Guthrie Zimmerman.

Decision Problem

The mission of the Black Duck Joint Venture is to provide information to land management agencies and organizations as to which habitat management actions should be implemented to increases the continental carrying capacity for the American black duck (*Anas rubripes*; hereafter black duck). From the perspective of the habitat Joint Ventures (e.g., Atlantic Coast Joint Venture, Eastern Habitat Joint Venture) and Federal and State/Provincial land management agencies an important management context is dependence upon annual grant programs (e.g., the North American Wetland Conservation Act Grant, State Wildlife Grants) to fund habitat management. These organizations need a decision support tool that aids in the evaluation and selection of proposed projects to benefit black ducks. To meet the mission of the BDJV and the needs of its partners, the BDJV needs a model framework (i.e., decision support tool) that will allow it to:

1. Make management recommendations in the face of uncertainty that are consistent across spatial and temporal scales;
2. Aids in reducing key uncertainties regarding black duck limiting factors and the influence of habitat management.

Background

Legal and regulatory context

The conservation and management of the black duck is governed by Migratory Bird Treaty Act (MBTA) of 1918. The MBTA implements the 1916 Migratory Bird Convention (MBC) between the United States and Great Britain (for Canada) which provides protection for birds that migrate between the U.S. and Canada. Under the MBTA and MBC the federal governments of the U.S. and Canada have responsibility for protecting and managing migratory birds including the black duck. The MBTA prohibits the pursuit, hunting, take, capture, kill (or attempt any of the aforementioned), possession, sale, purchase or delivery of any migratory bird (including any part, nest, or egg) unless permitted by regulations. Annual sport harvest of migratory birds, including black ducks, is allowed under the MBTA when authorized by the Secretary of the Interior (in the U.S.) and Minister of Environment (in Canada).

In the U.S. management of the black duck is the responsibility of the U.S. Fish and Wildlife Service (USFWS). Within the USFWS the management of the black duck is covered under three inter-related programs including the Birds of Management Concern, Focal Species, and North American Waterfowl Management Plan. At the state level the black duck has been identified as a "Species of Greatest Concern" by 23 states (Table 1).

Socio-political context

Historically, the black duck was the most abundant freshwater duck species in eastern North America (Fig. 1; Longcore et. al. 2000*b*) and until recently, it was also the most heavily harvested species in the region. Black duck harvest management is unique in the waterfowl community because traditionally the distribution of annual harvest has been approximately equal between the two countries. In contrast, the U.S. harvests the majority of other waterfowl species. Thus, a primary goal of black duck harvest management is to maintain equity in black duck harvest opportunities between the two countries. This requires greater cooperation between the U.S. and Canada and adds a political dimension not confronted by harvest management for other waterfowl species such as the mallard (*Anas platyrhynchos*).

The total annual harvest of black ducks declined significantly between the early 1970s and 2009 (Fig. 2). The decline in total harvest in the early 1980s coincided with the implementation of restrictive regulations in the U.S. and Canada beginning in 1983. Estimated harvest rates of adult male and female black ducks have been relatively stable around 7%—9% since 1990 (Fig. 3). Estimated harvest rates of juvenile male and female black ducks increased in 1996—1997 coinciding with the implementation of adaptive harvest management for eastern mallards and have remained relatively constant at 16%—17% (Fig. 3). Wildlife managers in Canada and the

U.S. are currently developing an adaptive harvest management framework for black ducks based on three fundamental goals:

a. Maintain a black duck population that meets legal mandates and provides consumptive and non-consumptive use commensurate with habitat carrying capacity;
b. Maintain societal values associated with the waterfowl hunting tradition; and
c. Maintain equitable access to the black duck resource.

Management Context

In response to the decline of the black duck population, government (Federal, State, and Provincial) and non-government agencies in Canada and the U.S. have implement multiple recovery programs/plans to restore the population to desired levels. These programs use a variety of "hard" (i.e., obligated program) and "soft" (i.e., grant) money to implement population and habitat management activities, monitoring, and research to restore the black duck population. Further, these programs work at different spatial scales (e.g., continental, regional, and local) to meet specific program objectives related to black ducks. For example, the North American Waterfowl Management Plan is designed to grow waterfowl populations to desired population levels via regional partnerships (i.e., Joint Ventures) that implement on the ground habitat management. A key funding sources for the Joint Ventures is the North American Wetlands Conservation Act (NAWCA) which provides significant funds for habitat management. The Joint Ventures need a tool to aid in the development and evaluation of NAWCA proposals designed to benefit black ducks at the regional scale. In contrast state and provincial conservation agencies often develop 5-year habitat management plans and need a tool to aid in the implementation of black duck habitat management at the local scale. Similarly, the U.S. Fish and Wildlife National Wildlife Refuge System (NRWS) develop and implement black duck habitat management plans at both the regional scale (i.e., Northeast region) and local scale (i.e., individual refuge). The NWRS also needs decision support tool to aid in the development of black duck habitat management plans across refuges and at individual refuges. The migratory bird programs of the U.S. Fish and Wildlife Service and Environment Canada's Canadian Wildlife Service implement management programs at the continental scale and need a tool to aid in determining which actions to implement and where to implement them. It is important to note the goals and objectives of the various programs do not always correspond and in a few cases may conflict. However, there are three common questions voiced by all of these programs

1) how many acres do we need to meet our black duck goal?
2) which parcels should we work on? and
3) what type of habitat management should we do?

Ecological context

The black duck population experienced a drastic (>50%) and long-term decline between the 1950s and 1990s (Fig. 4). Today, indices of abundance and productivity paint a mixed picture of population growth making the status and sustainability of the black duck uncertain. Based on mid-winter inventory (MWI) data the average finite growth rate between 1990 and 2010 was 0.99 (± 0.0.032 se, 95% CI 0.93—1.06; Fig. 4). However, the trend differed between the Atlantic Flyway ($\bar{x}$ = 1.0, ±0.032 se, 95% CI 0.94—1.06; Fig. 4) and the Mississippi Flyway ($\bar{x}$ = 0.99, ±0.0.62 se, 95% CI 0.86—1.11; Fig. 4). Similarly, a recent analysis of Christmas Bird Count (CBC) data suggested regional variation in population trends of black ducks (Link et al. 2006). The CBC provides data over a larger portion of black duck winter range than the MWI and indicated black ducks are declining in the southern and central portion of wintering range but populations in the northeastern range are stable (Link et al. 2006).

Estimates of the breeding population between 1990 and 2010 suggest the black duck population is stable or slightly increasing (Fig. 5). The mean finite growth rate between 1990 and 2010 based on the integrated breeding population estimate was 1.04 (± 0.04 se, 95% CI 0.96—1.12). However, this estimate only applies to that portion of the black duck breeding population covered by the initial surveys and may not reflect the overall population growth rate. Estimates of black duck wintering and breeding populations in 2010 were 223,472 and 760,400, respectively.

In contrast to these population indices, estimates of age ratios based on band return and hunter survey data indicate black duck productivity is highly variable, but slowly declining since the mid 1970’s (Fig. 6). More recently there was a drastic decline in fall age ratios in 1987 (Fig. 6). These data suggest the population may be at risk of continued or even accelerated decline in the future.

Researchers and managers have proposed several hypotheses to explain the historic decline of black ducks including over-harvest, competition and hybridization with mallards, decrease in quality and quantity of wintering and breeding habitat, and environmental contaminants (Conroy et al. 1989, Rusch et al. 1989, Longcore et al. 2000 *a,b*, Merendino et al. 1993, Nudds et al. 1996, Conroy et al. 2002, McAuley et al. 2004, Zimpfer and Conroy 2006). Research into each of these hypotheses has provided valuable insight into black duck ecology and management. However, the black duck community has not reached consensus regarding the cause of the population decline or current limiting factors.

Black duck population growth is influenced by a multitude of density-dependent and independent factors that occur at multiple spatial and temporal scales. These factors can either limit the population by decreasing black duck productivity (i.e., reproduction and recruitment of young into the fall population) or seasonal survival. It is safe to assume that limiting factors are dynamic so it is useful to categorize them into immediate (i.e., on-going) and emerging (i.e., long-term) threats. For example, the loss and degradation of habitat due to human activities (e.g., housing development along coastal marshes) is an immediate threat to black duck conservation (Fig. 7). Emerging threats may exacerbate existing limiting factors or introduce new limiting factors (Fig. 7). The best example of this is climate change. Depending on the rate and magnitude of change (i.e., changes in seasonal temperature and precipitation patterns) climate change may only cause an intensification of existing limiting factors. For example, the combination of urbanization and rising sea level (due to climate change) along the Atlantic coast will result in an accelerated loss of winter habitat and intensify density-dependent limiting factors currently influencing winter survival. Alternatively, black ducks may also experience new limiting factors such as novel diseases introduced to eastern North America as function of warmer and wetter conditions. The keys to addressing both immediate and emerging threats are: 1) to understand the functional relationships between density, habitat characteristics, and black duck vital rates, 2) understand how management can influence these relationships to increase the targeted vital rate, and 3) understand how climate change will influence habitat characteristics and the associated relationships with black duck vital rates.

The primary (hypothesized) limiting factors affecting black ducks are: 1) habitat loss, 2) habitat degradation, 3) inter-specific competition, and 4) harvest. Importantly, it is safe to assume all of these factors are occurring and influence black duck population growth and sustainability. The important questions are which factors are having the greatest impact and which factors are amenable to management.

Decision Structure

Objectives

Discussions across the black duck management community (and waterfowl management community at large) repeatedly identify 3 common fundamental objectives:

I. Maintain a black duck population abundance and distribution that meets legal and policy (i.e., North American Waterfowl Management Plan) mandates;

II. Maintain habitat carrying capacity to support desired population abundance and distribution; and

III. Maintain consumptive and non-consumptive recreational opportunities commensurate with habitat carrying capacity.

These fundamental objectives are inter-dependent (Fig. 8) and cannot be achieved in isolation. The financial and political support for black duck conservation (including population and habitat management) is derived from recreationists, particularly waterfowl hunters. The continued and future support from these constituents is dependent upon continued existence of the black duck population and habitat base to interact with the population. Achieving a desired population goal is dependent upon financial and political support and sufficient habitat base. The achievement of desired habitat across the landscape is predicated upon a desire of recreationist to have for a healthy black duck population. These inter-relationships dictates the fundamental objectives of black duck conservation, however the relative value of each objective may vary across programs depending on the scale of operation and engagement from recreationists. Further the optimal policy for achieving these objectives will differ based on the weight placed on each objective. For the purposes of this initial prototype we focused on developing a decision support tool that will maximize population size and continental harvest by increasing continental carrying capacity (K) via habitat management constrained by budgetary limits.

Alternative actions

Wildlife managers have a variety of potential management actions available to grow the black duck population (Table 2). For the purposes of this program we constrained our options to habitat related actions and classified each into 1 of 3 categories:

1) habitat acquisition/protection;
2) habitat restoration;
3) habitat enhancement.

To facilitate the development of a prototype framework we focused our efforts on habitat acquisition/protection. Continued development of this framework will consider all three (and potentially more) habitat management categories, incorporation of rate of habitat loss, and more detailed cost information.

Predictive model

We developed a conceptual model of black duck annual population dynamics and habitat limiting factors (Fig. 9). We identify hypotheses about relationships between black duck vital rates (by season) and habitat/landscape features (Table 3). We did not give consideration to logistical/financial constraints when identifying potential hypotheses regarding limiting factors. We focused the discussion on habitat characteristics and not other factors (i.e., mallard abundance, harvest, weather). However, we recognize these factors do influence black duck population dynamics and must be considered in the future, but since they are not directly amenable to habitat management we placed them in the parking lot. After completing an initial list of hypotheses we went through an iterative process to more explicitly define the hypotheses and delete hypotheses that will not be considered in the future.

Starting with the breeding season and black duck productivity, we hypothesized there is a significant difference (in terms of biology and management options) between the “Un-settled boreal forest” (i.e., Bird Conservation Regions [BCR] 7 & 8) and the “settled transitional/boreal forest” (i.e., BCR12 & 14) of Canada (Table 3). The un-settled boreal forest is relatively pristine compared to other regions within the black duck range. The main threats to habitat quality and quantity are hydro-electric development, mining, and timber harvest. Black duck limiting factors in this region are probably natural, density-dependent processes driving by habitat quality (i.e., wetland complexity) at the local scale. The group agreed management options in the Un-settled forest habitat are primarily government and industry based policies that acquire and protect undeveloped or undisturbed landscapes.

In the "Settled transitional/boreal forest of southern Canada black duck habitat quality and quantity has been significantly influenced by human activities including urbanization, agriculture, timber harvest, and industrialization. Black duck limiting factors in this region may include natural, density-dependent processes such as wetland complexity, but also human disturbance, amount of agriculture, and area of forested wetlands. In this region habitat management options include habitat acquisition/protection, restoration and enhancement at multiple scales (e.g., regional, local, and individual wetland).

We hypothesized black duck survival differs by season including fall (1 September to 31 December), winter (1 January to 15 March), and spring (16 march to 31 May). During the fall survival is a function of age and the amount of habitat or amount of refugia (area closed to hunting) across the landscape, harvest policy and abundance of mallards (Table 3). Winter survival is hypothesized to be a function of region (i.e., BCRs 13, 14, 22, 23, 24, 27, and 30), food availability and quality, human disturbance, juxtaposition of loafing and feeding areas, and days of ice cover. Spring survival was initially assumed to be relatively high and stable and not limited by habitat. This assumption has been questioned and will be revisited in future development of the model framework.

We developed the first prototype of the model based on the conceptual model of the biological system (Fig. 9) and the management system (Fig. 10). To facilitate development of the initial prototype and to explore the potential model framework we simplified the demographic model to 2 breeding regions (i.e., un-settled and settled areas of Canada) and 2 wintering regions (i.e., mid-Atlantic [BCR 30] and all others). Future iterations of the model framework will incorporate the full spatial structure identified in the conceptual model.

We developed a balance equation assuming density dependent growth to describe black duck population dynamics (eq. 1).

$$N_t = ((N^{a,i}_t * R^i_t) * S^{j,i}_{t,f} * S^{j,i}_{t,w} * S^{j,i}_{t,p})) + (N^a_{,i} t * S^{a,i}_{t,s} * S^{a,i}_{t,f} * S^{a,i}_{t,w} * S^{a,i}_{t,p}) \quad \text{(eq. 1)}$$

Where:

N_t is the estimated breeding population in year t in area i (unsettled or settled).
R_t is black duck productivity in area i (unsettled or settled) defined as the ratio of juvenile to adult black ducks at the start of the fall season.
S_t is seasonal survival (fall [f], winter [w], spring [p], and summer [s]) for juveniles (j) and adults (a) in year t and area i (mid-atlantic or other).

Hypotheses:

1. Black ducks are regulated via density dependence.
    a. via changes in winter survival (S_w) (Fig 11),
    b. via winter survival (S_w) (Fig 12),
    c. via both winter survival (S_w) and productivity (R_t),

Assumptions:

1. Fall survival is a function of harvest (harvest is additive). Harvest rates are constant over time but differ by age class (juvenile=0.14; adult=0.10). Subsequent analyses indicated mean adult harvest rate is 0.07 and mean juvenile harvest rate is 0.14.
2. Spring survival is assumed to be constant at 0.90.
3. Adult summer survival was assumed to be constant, but differed between breeding areas (unsettled = 0.9, settled 0.8).
4. Inverse logit relationship between winter survival and abundance with slope of 5 and 3 in the mid-Atlantic and other wintering areas respectively and a slope of -12 in all regions.
5. Winter survival ranged from 0.5—0.9 in the mid-Atlantic region and 0.45—0.85 in all other areas.

6. Inverse logit relationship between productivity and abundance with minimum age ratio of 0.5 and a maximum of 2.0.
7. Slope (-6 and -12) differed between the unsettled and settled areas respectively.
8. Intercept =2 for both regions.
9. Continental carrying capacity (in the absence of harvest) is 1.75 million
10. 70% of the breeding population breeds in the unsettled region.

Decision Analysis

The purpose of the predictive model is to inform where and which type of habitat management actions should be implemented through an optimization process designed to 1) maximize breeding black duck abundance, and 2) maximize black duck harvest opportunity within a budget constraint (Fig. 13). We assumed equal weight on the population and harvest opportunity goal (i.e., 40% each) and 20% weight on cost. In the absence of quantitative data regarding the cost of habitat management actions across the black duck range we developed hypothetical relationships as placeholders in the initial prototype. We assumed the cost of managing 1 unit in the unsettled breeding area is least expensive and set it as the baseline of 1. The cost of managing 1 unit in the setted breeding area was 10 times, mid-Atlantic was 50 times, and other wintering area was 30 times the cost of the baseline. The cost and influence of habitat delivery was constant across habitat types (e.g., salt marsh versus forested wetland) within a season. The optimization function was:

$$U_T = (0.4*U_N) + (0.4*U_H) + (0.2*U_c) \qquad \text{(eq.2)}$$

Where:
U_T is total utility,
U_N is population utility,
U_H is harvest utility, and
U_C is the cost utility.

The product of the analysis will be decision matrix consisting of budget levels and regional habitat management actions (Table 4 & Fig. 14).

Uncertainty

We identified several sources and of uncertainty that may influence the optimal policy (Table 5). We conducted a preliminary assessment of the influence of different hypotheses of how habitat management in the mid-Atlantic region influences density dependent survival. Specifically we assume habitat management had a greater influence on survival compared to baseline inputs. The results suggested the optimal policy would be a greater mix of habitat management throughout black duck range compared to the baseline inputs (Table 6, Fig. 15). These results and the previously identified sources of uncertainty indicate the final framework and optimal policy will be highly influenced by our assumptions and current state of knowledge. This uncertainty suggests that black duck habitat management should be conducted within an adaptive management framework designed to inform our decision making and to reduce key uncertainties over time.

Discussion

Value of decision structuring

We felt the structured decision making process helped us keep our focus on the management context (i.e., growing the black duck population to desired levels via habitat management). The underlying modeling process provides a useful way to explicitly identify assumptions and knowledge gaps that must be informed through monitoring and directed research. These monitoring and research needs, in turn, provide a focus and direction for the Black Duck Joint Venture. Finally, the modeling process provides a way for incorporating and synthesizing research and modeling data to improve management. Due to its transparent and intuitive process, the structured decision making process also provides a concrete foundation for communicating the objectives of black duck management and justification for resulting recommendations.

Further development required

We recognized the resulting prototype is a crude formulation of the framework, however we think the critical components and linkages were identified thus it provided a basic skeleton for the framework. We identified a variety of issues that must be addressed before the framework can be submitted to our partners for consideration and implementation (Table 7). Most importantly, we believe that for this framework to be useful it needs to be fully developed and vetted by our partners within the next 2 years. Further, development of the framework will required the dedicated time of full-time staff with support from the current development team.

Prototyping process

The rapid prototyping process was critical to moving this project forward. First, rapid prototyping allowed us to piece together each part of an adaptive management framework and allowed us to develop a clearer idea of the objectives. Second, having an initial prototype will improve our ability to communicate the objectives, methods, and products of a fully developed adaptive framework to our partners (i.e., what will the resulting recommendations look like?). Finally, the rapid prototyping process allowed us to identify important information gaps that can be immediately incorporated into the Black Duck Joint Venture's monitoring and research programs.

Recommendations

We recommend the Joint Ventures (i.e., Black Duck Joint Venture and associated Habitat Joint Ventures) and other partners commit resources to hiring a full-time, temporary position to organize the necessary data, conduct analyses, and develop model code to complete the development of an adaptive framework to inform black duck habitat management. We also recommend the Black Duck Joint Venture convene a series of workshops to explain the purpose of this model framework, obtain input concerning model components, and obtain buy in from partners.

Literature Cited

Conroy, M. J., G. R. Costanzo, and D. B. Stotts. 1989. Winter survival of female American black ducks on the Atlantic coast. Journal of Wildlife Management 53:99–109.

Conroy, M. J., M. W. Miller, and J. E. Hines. 2002. Identification and synthetic modeling of factors affecting American black duck populations. Wildlife Monographs 150.

Link, W. A., J. R. Sauer, and D. K. Niven. 2006. A hierarchical model for regional analysis of population change using Christmas bird count data, with application to the American black duck. Condor 108:13–24.

Longcore, J. R., D. G. McAuley, D. A. Clugston, C. M. Bunck, J.-F. Giroux, C. Ouellet, G. R. Parker, P. Dupuis, D. B. Stotts, and J. R. Goldsberry. 2000*a*. Survival of American black ducks radiomarked in Quebec, Nova Scotia, and Vermont. Journal of Wildlife Management 64:238–252.

Longcore, J. R., D. G. McAuley, G. R. Hepp, and J. M. Rhymer. 2000*b*. American black duck (*Anas rubripes*). *In* the Birds of North America, No. 481 (A. Poole and F. Gill, editors). The Birds of North America, Inc., Philadelphia, PA.

McAuley, D. G., D. A. Clugston, and J. R. Longcore. 2004. Dynamic use of wetlands by black ducks and mallards: Evidence against competitive exclusion. Wildlife Society Bulletin 32:465-473.

Merendino, M. T., C. D. Ankney, and D. G. Dennis. 1993. Increasing mallards, decreasing American black ducks: more evidence for cause and effect. Journal of Wildlife Management 57:199-208.

Nudds, T. D., M. W. Miller, and C. D. Ankney. 1996. Black ducks: Harvest, mallards, or habitat? Pages 50-60 *in* J. T. Ratti, editor. Seventh International Waterfowl Symposium. Institute for Wetland and Waterfowl Research, Memphis, TN USA.

Rusch, D. H., C. D. Ankney, H. Boyd, J. R. Longcore, F. Montalbano, J. K. Ringelman, and V. D. Stotts. 1989. Population ecology and harvest of the American black duck. Wildlife Society Bulletin 17:379-406.

Zimpfer, N. L., and M. J. Conroy. 2006. Modeling movement and fidelity of American black ducks. Journal of Wildlife Management 70:1770-1777.

Table 1. Atlantic and Mississippi Flyway States that identified the American black duck as a "species of greatest conservation need" as part of State Action Plans.

State	***Flyway***	***State***	**Flyway**
Connecticut	Atlantic	West Virginia	Atlantic
Delaware	Atlantic	Alabama	Mississippi
Florida	Atlantic	Arkansas	Mississippi
Maine	Atlantic	Illinois	Mississippi
Maryland	Atlantic	Kentucky	Mississippi
New Hampshire	Atlantic	Michigan	Mississippi
New Jersey	Atlantic	Mississippi	Mississippi
New York	Atlantic	Ohio	Mississippi
Pennsylvania	Atlantic	Wisconsin	Mississippi
Rhode Island	Atlantic	Alabama	Mississippi
South Carolina	Atlantic	Arkansas	Mississippi
Vermont	Atlantic	Kentucky	Mississippi
Virginia	Atlantic	Minnesota	Mississippi

Table 2. Partial list of potential management actions that could be used by resource managers to try to increase the black duck population.

Category	**Sub-category**	**Action**
Population Management	Black duck population	Captive raise and release black ducks
	Black duck population	Trans-locate wild black ducks
	Black duck population	Restrict/close hunting
	Black duck population	Decrease disturbance
	Non black duck populations	Predator control
	Non black duck populations	Reduce eastern mallard population and distribution
	Non black duck populations	Stop release of farm raised mallards
	Non black duck populations	Reduce (control) abundance of resident Canada geese (*Branta canadensis*) and snow geese (*Chen caerulescens*)
	Non black duck populations	Restore beaver (*Castor canadensis*) populations.
Habitat Management	Habitat Acquisition/Protection	Fee title acquisition of undeveloped land parcels
	Habitat Acquisition/Protection	Conservation easements
	Habitat Acquisition/Protection	Cooperative agreements
	Habitat Acquisition/Protection	Leases

Table 2. Continued.

Category	Sub-category	Action
	Habitat Acquisition/Protection	Policy development and implementation (i.e., Conservation Reserve Program, Wetland Protection Act)
	Habitat Acquisition/Protection	Financial incentives
	Habitat Acquisition/Protection	Urban/Agricultural growth planning
Habitat Management	Habitat Restoration	Restore tidal wetland hydrology
	Habitat Restoration	Restore drained wetlands
	Habitat Restoration	Restore riparian systems
	Habitat Restoration	Restore forested wetlands in agricultural areas
	Habitat Restoration	Restore submerged aquatic vegetation
	Habitat Restoration	Eliminate/reduce invasive species
	Habitat Enhancement	Reduce/minimize flight distance between loafing and feeding areas
	Habitat Enhancement	Reduce human disturbance (i.g., automobiles and pedestrians) around feeding and loafing areas.
	Habitat Enhancement	Improve water level management on managed wetlands
	Habitat Enhancement	Artificial winter feeding
	Habitat Enhancement	Eliminate/reduce invasive species
	Habitat Enhancement	Reduce human disturbance (e.g., automobile traffic, recreational disturbance, density of human structures)

Table 3. List of hypothesized black duck limiting factors that are a function of habitat characteristics and amenable to habitat management. Hypotheses in red were removed from future consideration in model development.

Breeding season: (1 April to 31 August)

Productivity (unsettled forest): Nest success

Ho: forest understory density (within half a mile of wetland complex) increases nest success

Ho: Increased wetland complex (as measured by Gollet index) increases nest success

Ho: Increasing road density decreases nest success

Ho: Increasing road density and reduced percent forest cover decreases nest Success (forestry practices influence predator community)

* This is probably not an important driver of the system.

Ho: Nest success increases with increasing spring body condition (body condition when leaving the wintering grounds)

Productivity (settled landscaped): nest success

Ho: Increased density of roads (index of human activity) decreases nest success

Ho: forest understory density (within half a mile of wetland complex) increases nest success

Ho: Increased wetland complexity (as measured by Gollet index) increases nest success

Ho: Increasing road density decreases nest success

Ho: Increasing road density and reduced percent forest cover decreases nest Success

Ho: Nest success increases with increasing abundance of wetlands in ag areas

Ho: Nest success increases with increasing area of forested wetlands in urbanized areas

Ho: Nest success decreases with decreasing cover around wetlands

Ho: Forest wetlands smaller than a certain threshold decreases nest success (area Sensitivity index)

Ho: Nest success increases with increasing spring condition

In general the group doesn't feel like nest success is a limiting factor in population growth.

Ho: nest success (or settling) decreases with increasing human settlement.

From a modeling standpoint nest success is a combination of settling rate and nest success. Currently, settling rate is monitored by BPOP. Assume BPOP location is also the location of nest.

Productivity (unsettled forest): duckling survival

Ho: Ducking survival increases with increasing wetland complexity (as indexed by Gollet Score)

Wetland productivity is increases with increasing soil productivity

Ho: Duckling survival decreases as brood density increases

Ho: The amount breeding habitat is decreasing resulting in decreasing duckling Survival

Ho: Duckling survival increases with increasing quality of brood rearing wetlands

Ho: Duckling survival increases with increasing food.

Ho: Duckling survival increases with increasing wetland vegetation.

Productivity (settled forest): duckling survival

Ho: Ducking survival increases with increasing wetland complexity (as indexed by Gollet Score)

Wetland productivity is increases with increasing soil productivity

Ho: The population is currently at breeding ground carrying capacity.

Ho: The amount breeding habitat is decreasing resulting in decreasing duckling Survival

Ho: The quality of brood rearing wetlands is decreasing resulting in decreasing duckling survival.

Ho: Decreasing amount of food in a wetland complex result in decreasing duckling survival.

Ho: Duckling survival increases understory cover next to wetland.

Ho: Duckling survival decreases with increasing human disturbance

Productivity (unsettled forest): hen survival (defined as survival during the nesting and brood rearing period).

Ho: Hen survival decreases with increasing clear-cutting (linear vs quadratic functional form); (what is the time scale of the benefits or detriments of clear-cutting)

Ho: Hen survival decreases with increasing forest fragmentation

Productivity (settled forest): hen survival

Ho: Hen survival decreases with increasing clear-cutting (linear vs quadratic functional form); (what is the time scale of the benefits or detriments of clear-cutting)

Ho: Hen survival decreases with increasing forest fragmentation

Ho: Hen survival decreases with increasing agricultural intensification (e.g., landscapes dominated by dairy are better than landscapes dominated by row crops)

<u>Winter Season</u> (Post-hunting season): (1 January to 15 March; start of winter season is defined as end of hunting in Canada).

Survival:

Ho: Survival increases with increasing energy availability

Ho: Survival increases with caloric availability

Ho: Survival decreases with increasing human disturbance

Ho: Survival decreases with increasing distance between foraging and loafing areas. (Goal is to minimize flight time)

Ho: Survival decreases if there 4 or more consecutive days of ice cover

i. This process may not apply in Atlantic Canada due to tidal activity.

Ho: Survival decreases if exceed X number of days at or below ABDU lower lethal temperature (Atlantic Canada)

Ho: Survival decreases with decreasing amount of habitat (D-D)

Ho: Survival decreases with decreasing visual buffer from human activity

Condition: group decided winter condition doesn't influence productivity; from evolutionary view we believe ducks don't carry stores during migration.

Migration: (fall) (1 September to 31 December)

Ho: Survival decreases with increasing harvest rate as determined by regulatory package

Ho: Survival increases with increasing non-hunting refugia

Ho: Survival is age dependent (due to differential harvest vulnerability)

Ho: Survival increases with increasing amount of available habitat (spread out the hunters)

- Assume food is not limiting during fall migration
- Assume harvest is additive and only mortality factor

Migration: (spring) (16 March to 31 May)

Survival during spring migration assumed to be high and very stable and not limited by habitat characteristics.

This assumption has been questioned by ABDU experts particularly concerning migration in the Mississippi Flyway and will be reconsidered in future development of the model framework.

Table 4. Fictional decision matrix of optimal habitat management actions across seasons and regions conditioned on budget and assuming relative higher benefit of habitat management in the mid-Atlantic region compared to the baseline.

	Number of Habitat Units Delivered on Breeding Grounds					
	Un-settled Breeding Region			Settled Breeding Region		
Budget	Acquired	Restored	Enhanced	Acquired	Restored	Enhanced
300	0	0	71	65	38	60
475	0	0	32	80	62	35
650	0	0	46	51	65	87
825	0	0	11	74	39	69
1000	0	0	28	81	21	26

	Number of Habitat Units Delivered on Wintering Grounds					
	Un-settled Breeding Region			Settled Breeding Region		
Budget	Acquired	Restored	Enhanced	Acquired	Restored	Enhanced
300	56	83	42	28	7	30
475	2	25	59	86	71	41
650	34	58	58	30	17	16
825	74	13	36	76	17	56
1000	73	1	24	8	64	92

Table 5. Partial list of potential sources of uncertainty that may influence the optimal policy regarding black duck habitat management.

Source of Uncertainty	
1	Hypothesized functional form of the density dependent relationships
2	Actual cost of habitat management action
3	Hypothesized influence of habitat actions on density dependent relationships
4	Risk of habitat loss/degradation across regions
5	Estimates of baseline vital rates
6	Specification of utility functions
7	Partial controllability of habitat management actions (i.e., probability of success).
8	Incorporation of additional habitat management actions (e.g., restoration)

Table 6. Fictional decision matrix of optimal habitat management actions across seasons and regions conditioned on budget and assuming relative higher benefit of habitat management in the mid-Atlantic region compared to the baseline.

Budget	Number of Habitat Units Delivered			
	Un-settled Breeding Region	Settled Breeding Region	Mid-Atlantic Wintering Region	Other Wintering Regions
300	29	0	0	0
475	34	0	0	0
650	52	4	3.4	13
825	44	9	3.5	17
1000	40	12	3.1	23

Table 7. Partial list of unresolved issues (in no particular order) that need to be addressed prior to implementation of an adaptive management framework black duck habitat management.

Issue	
1	Finalize alternative expression of density dependent (e.g., productivity and survival) to represent competing hypotheses.
2	Determine how to incorporate migration transition probabilities.
3	Incorporate the conceptual complexity of the non-breeding season (i.e., 5 wintering regions).
4	Incorporate mean estimates (and variance) of costs (in U.S. or Canadian currency units) associated with habitat management actions throughout black duck range.
5	Estimate current landscape conditions in each spatial unit.
6	Estimate net landscape change over a 5- or 10-year period.
7	Review and gain consensus regarding parameter estimates and functional forms.
8	Incorporate partial controllability (i.e., probability of success) for habitat management actions.
9	Incorporate habitat enhancement and restoration actions.
10	Reach consensus about how density dependent relationships are influenced by management actions designed to improve habitat quality versus habitat quantity.
11	Incorporate competing hypotheses about how management actions affect vital rates.
12	Determine appropriate time step for evaluating model predictions and updating.
13	Review and finalize cost utility function.
14	Incorporate risk parameter to represent predicted rate of habitat loss and or degradation in each region.
15	Determine how to capture system change (e.g., climate change).
16	Incorporate iterative decision context.
17	Develop harvest objectives, measurable attributes, and utility function in cooperation with the Black Duck Adaptive Harvest Management Working Group.

Figure 1. Distribution of the American black duck (*Anas rubripes*) (from Longcore et al. 2000).

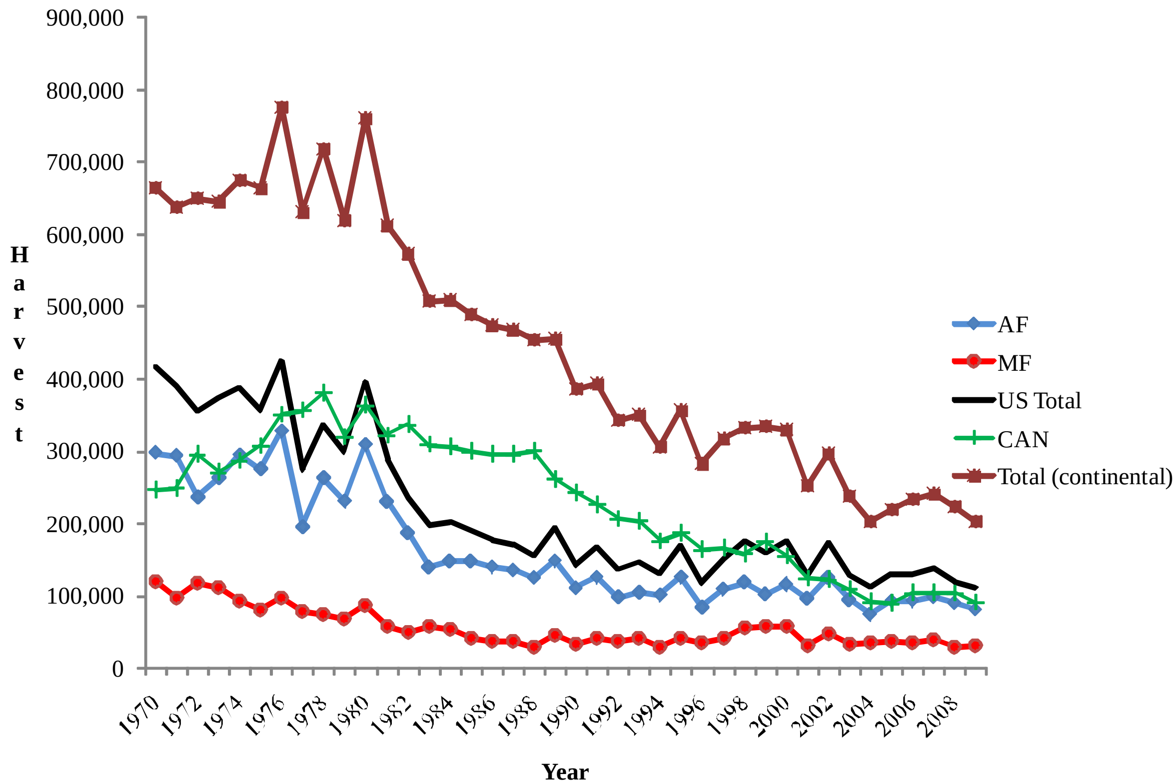

Figure 2. Trend in black duck harvest, 1970—2009.

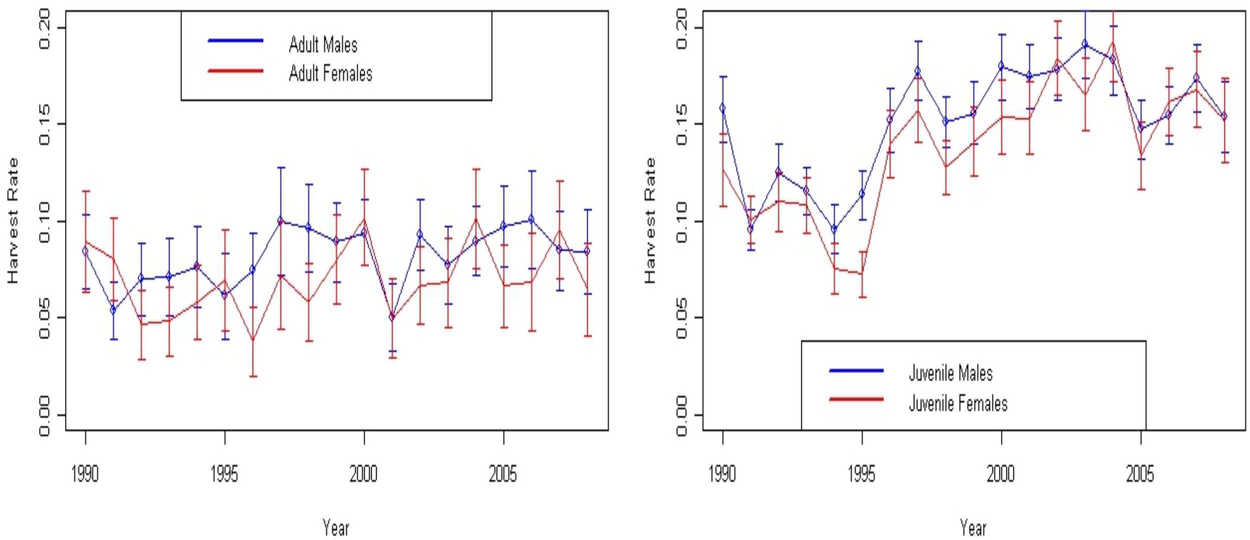

Figure 3. Trend in estimated black duck harvest rates by age and sex class, 1990—2008.

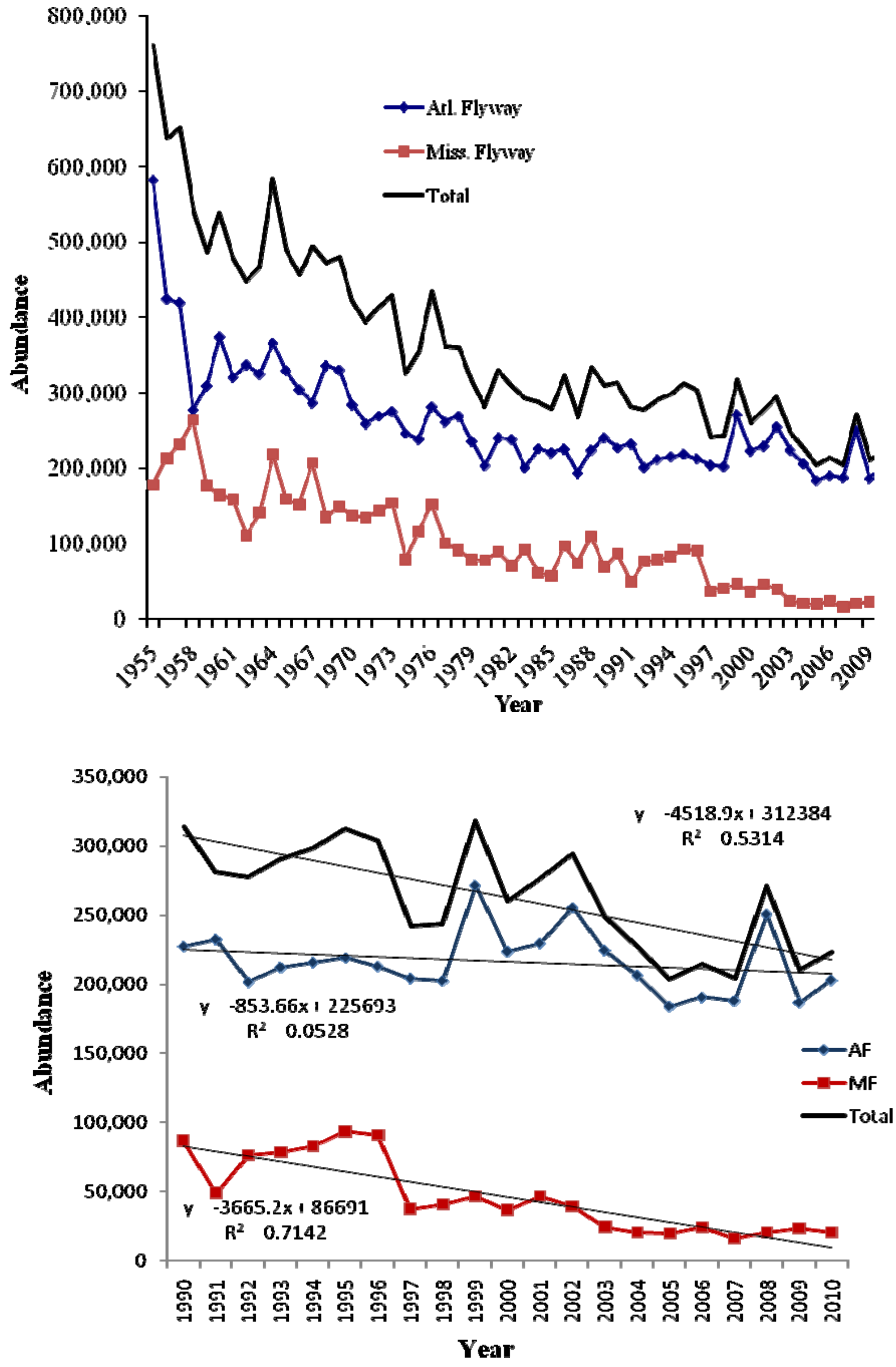

Figure 4. Trend in black duck winter abundance (in January) in the United States (1955—2010 top panel; 1990—2010 bottom panel) as measured by the U.S. Fish and Wildlife Service Mid-Winter Inventory (MWI).

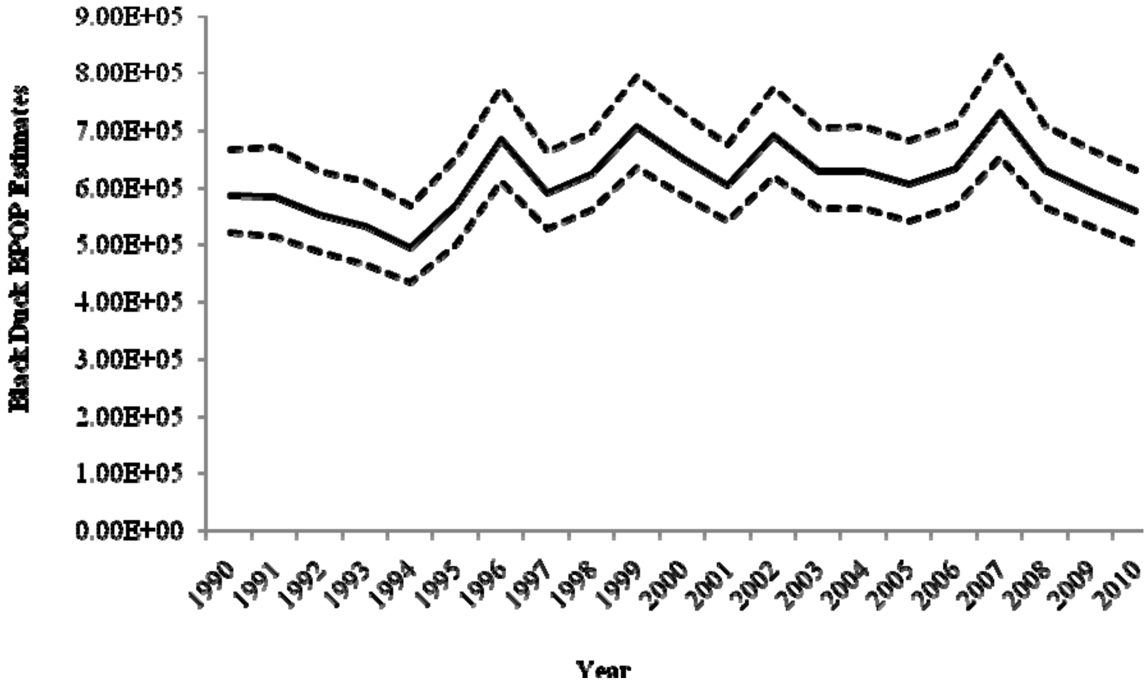

Figure 5. Trend in black duck breeding population abundance (1990—2010) as measured by the Integrated Eastern Waterfowl Survey.

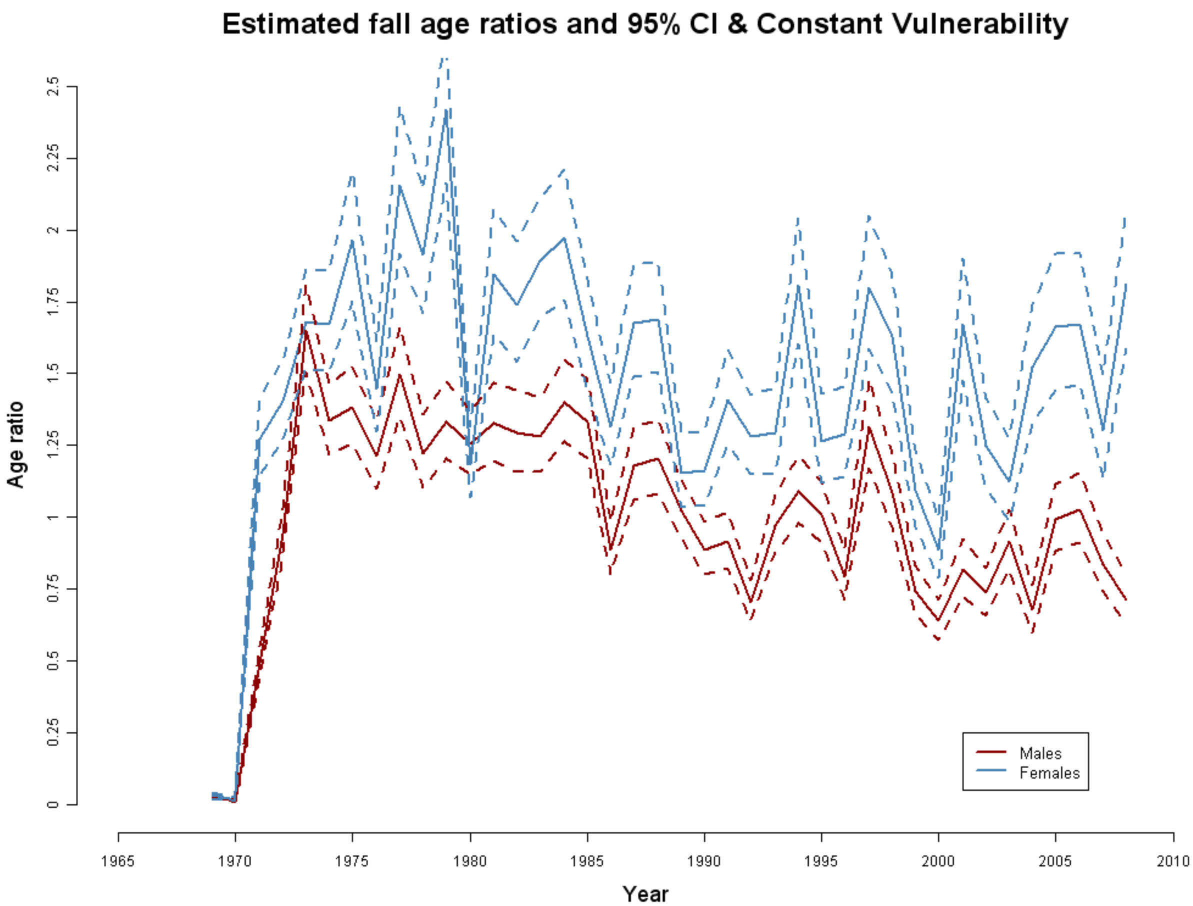

Figure 6. Trend in black duck pre-hunting season age ratios.

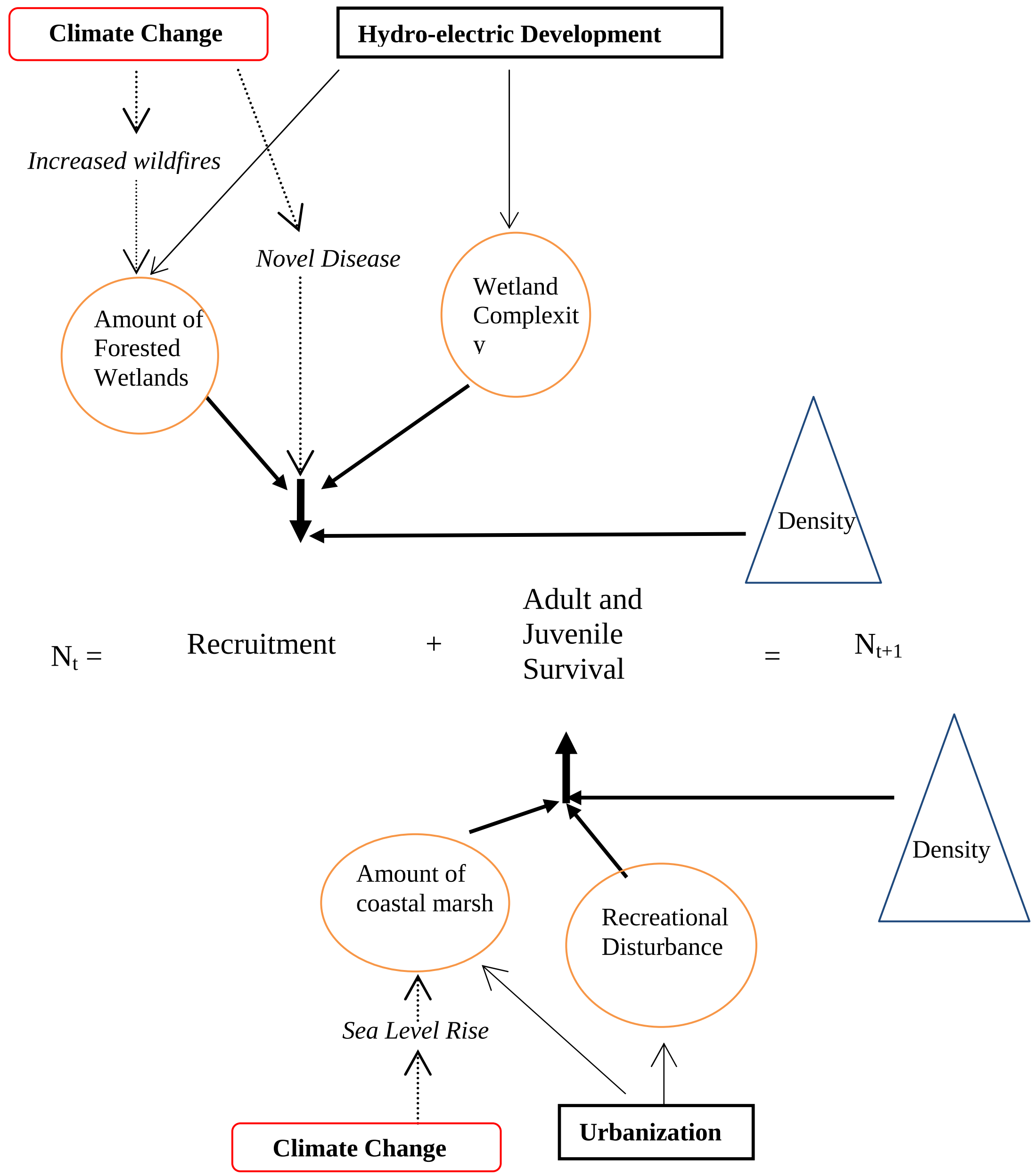

Figure 7. Conceptual diagram of black duck population dynamics, and immediate (i.e., habitat loss via hydro-electric development and urbanization) and emerging limiting factors (i.e., habitat loss via climate change).

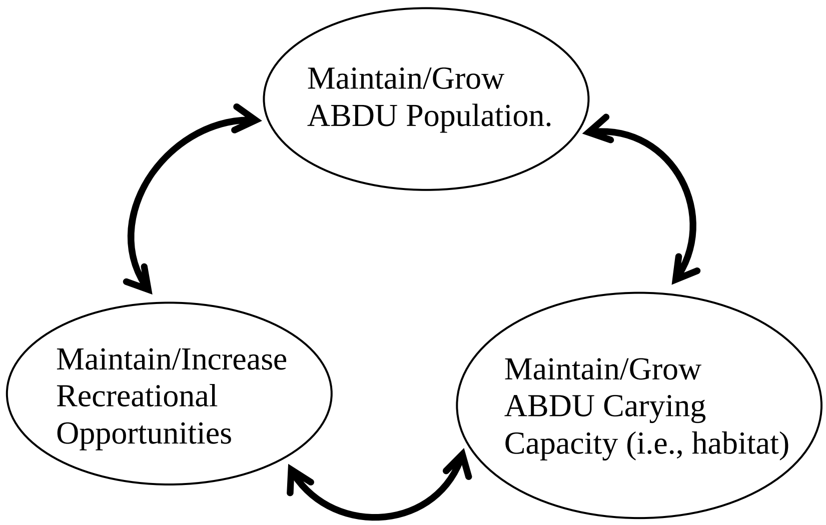

Figure 8. Inter-relationship of the fundamental objectives of black duck conservation.

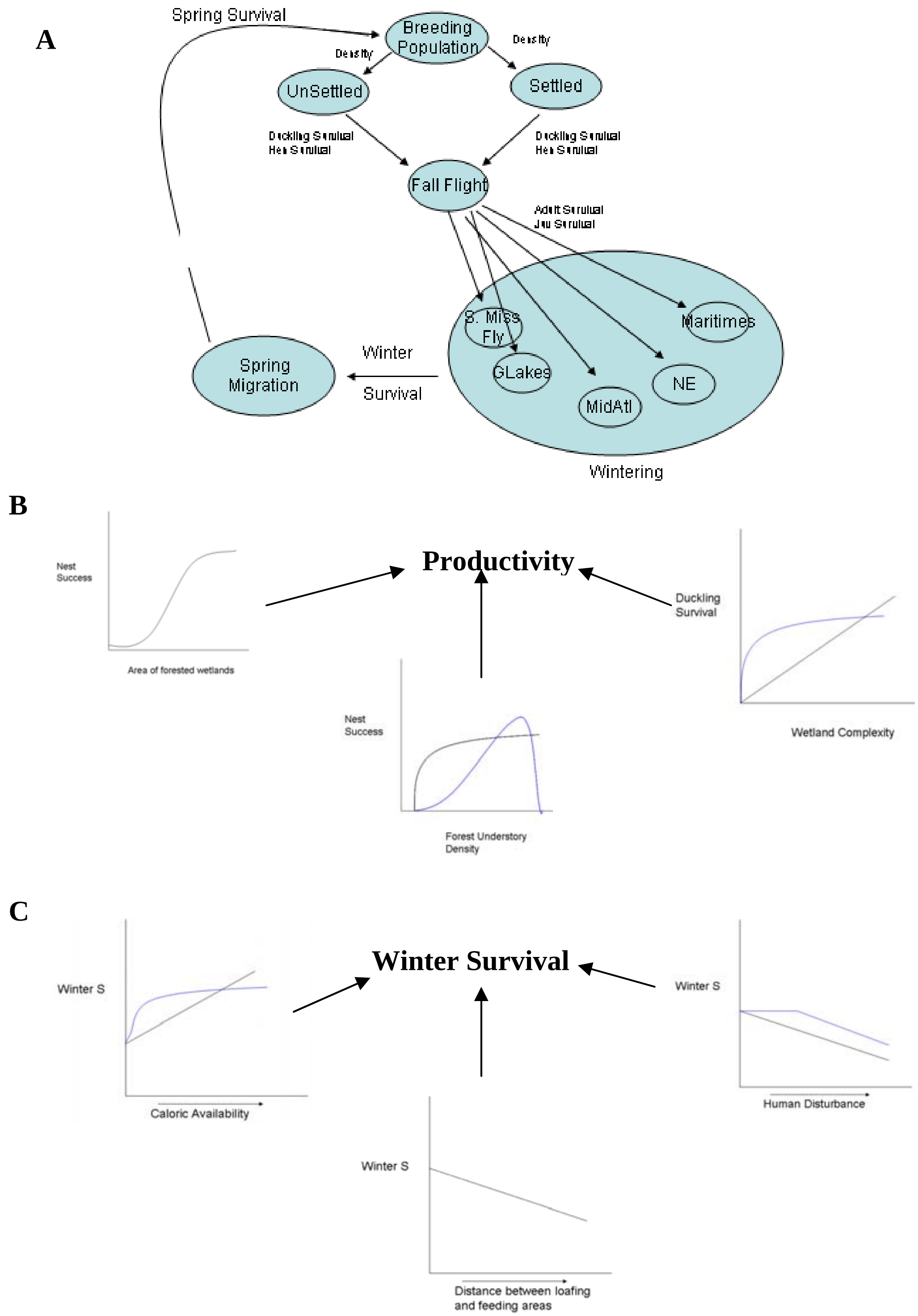

Figure 9. Conceptual model of black duck population dynamics and limiting factors: A) describes the annual life cycle, spatial structure, and key vital rates driving black duck population dynamics. B) describes hypothesized relationships between habitat characteristics and black duck productivity. C) describes hypothesized relationships between habitat characteristics and black duck winter (January—March) survival.

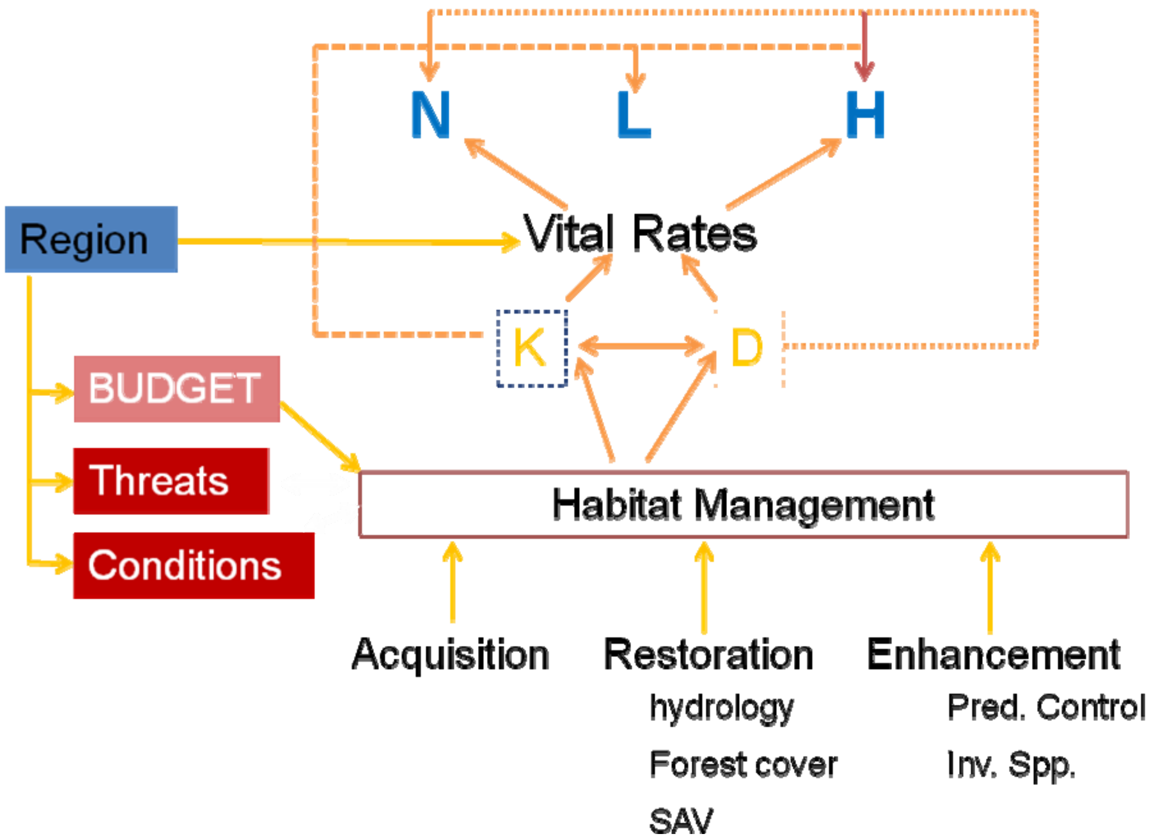

Figure 10. Conceptual model of the black duck management system designed to increase the black duck population by increasing continental carrying capacity via habitat management. Abbreviations include estimated breeding abundance (N), landscape conditions (L), continental harvest (H), continental carrying capacity (K), and regional black duck density (D). Black duck vital rates consist of season survival (summer, fall, winter, and spring) and recruitment.

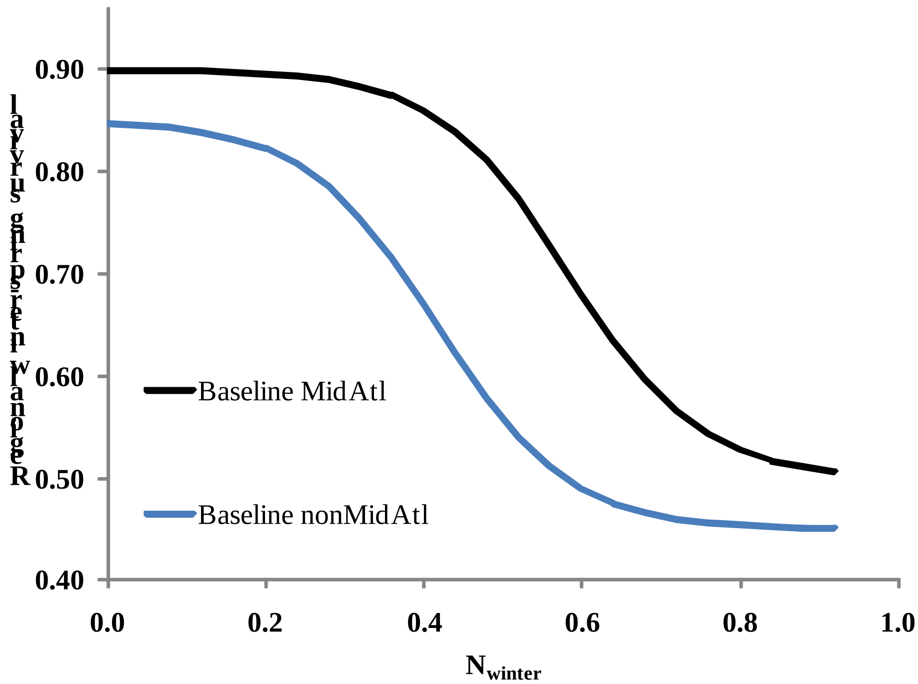

Figure 11. Hypothesized relationships between black duck winter survival and density.

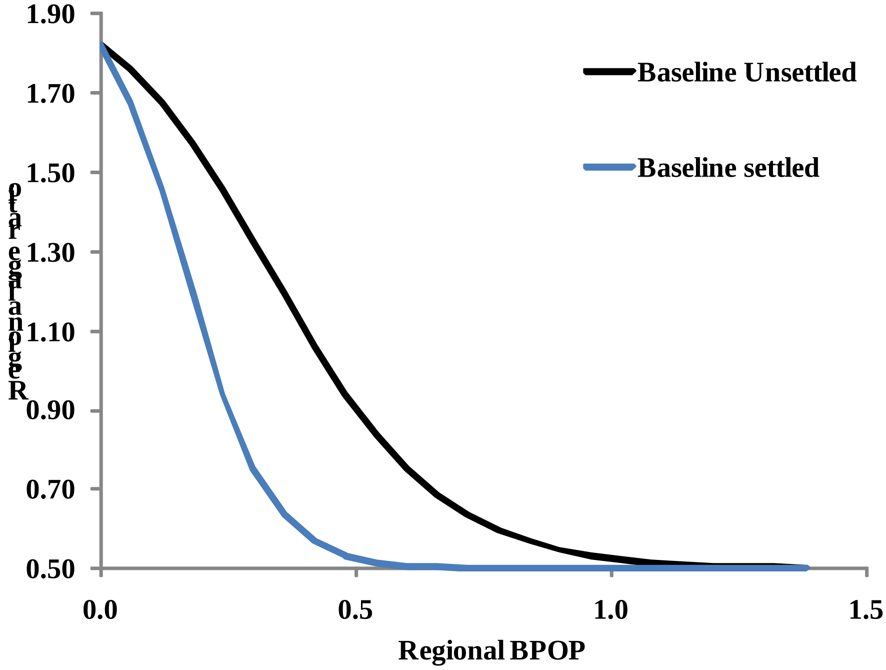

Figure 12. Hypothesized relationship between black duck productivity and density.

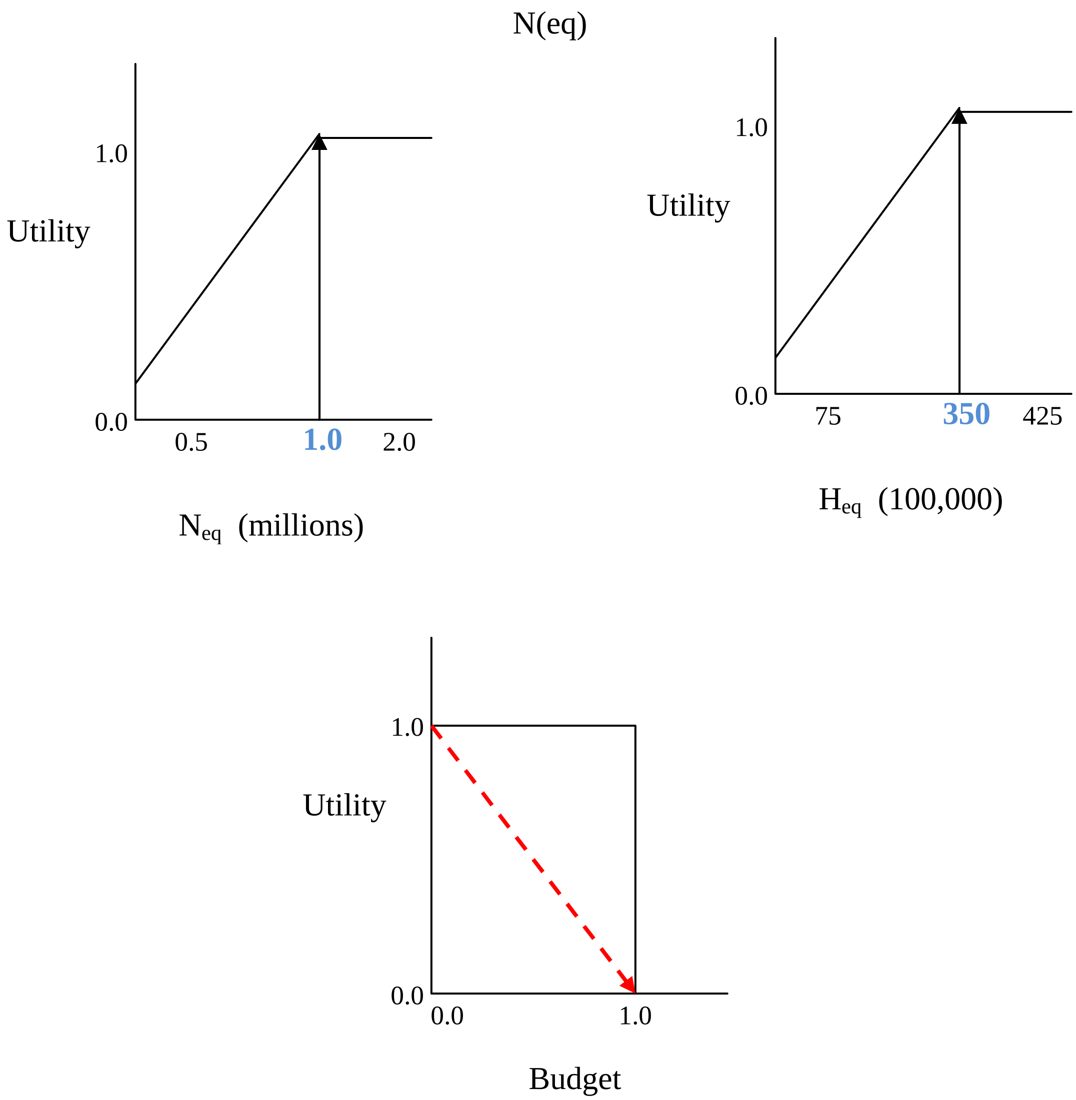

Figure 13. Utility functions (a) population utility, (b) harvest utility, and (c) two alternative expression of the budget constraint used in an optimization process to determine where and which habitat management actions will have the greatest impact on achieving the goals of the black duck conservation community.

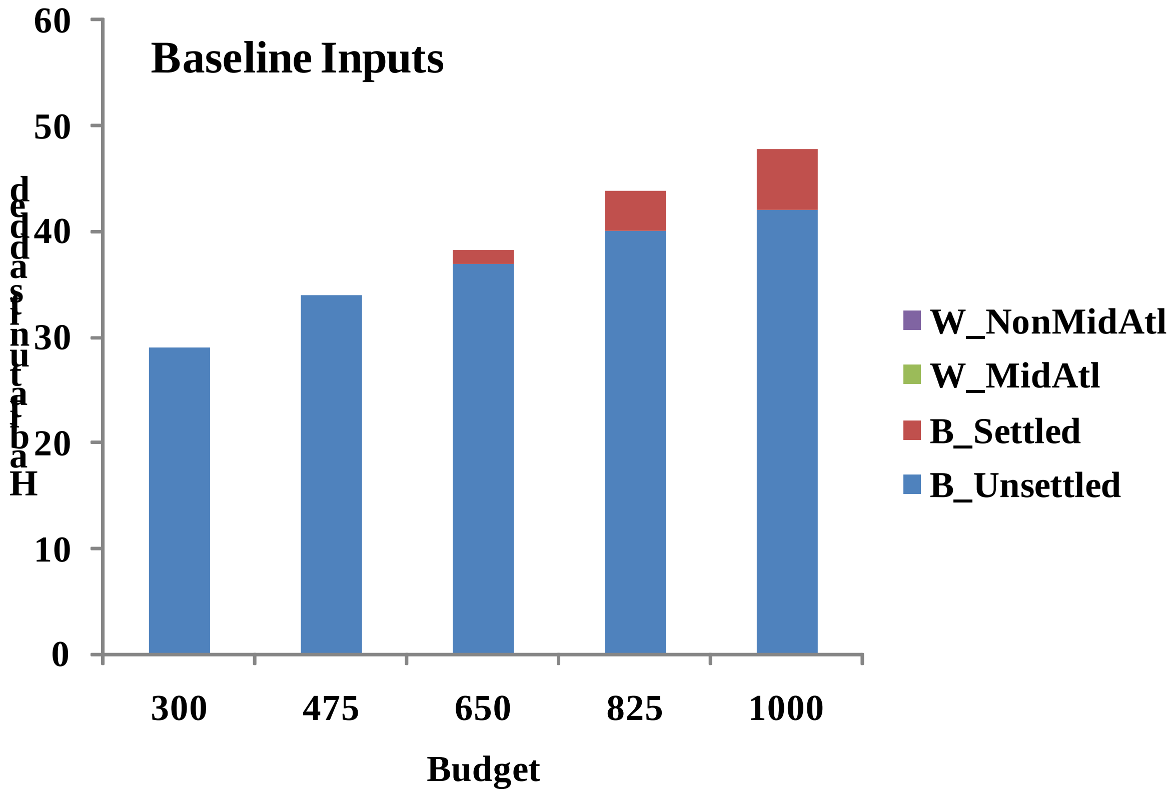

Figure 14. Fictional results illustrating the decision matrix of optimal black duck habitat management (i.e., acquisition and protection) conditioned on a budget.

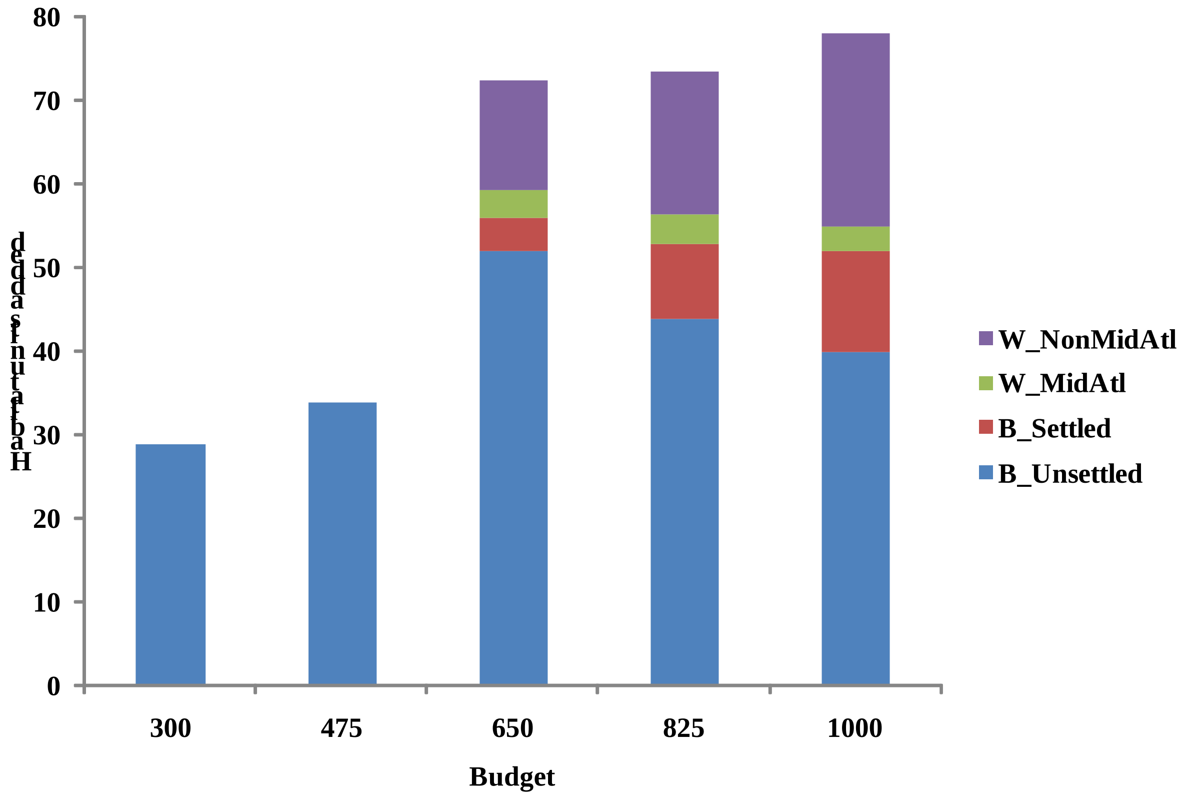

Figure 15. Fictional results illustrating the decision matrix of optimal black duck habitat management (i.e., acquisition and protection) conditioned on a budget and assuming a higher relative benefit of habitat management in the mid-Atlantic region compared to baseline.