Transactions of the Seventy-first North American Wildlife and Natural Resources Conference

Conference Theme:
Natural Resource Conservation. . . The Other Homeland Security

March 22 to 25, 2006
Hyatt Regency Columbus
Columbus, Ohio

Edited by
Jennifer Rahm

Published by the
Wildlife Management Institute
Washington, DC
2006

The annual *Transactions of the North American Wildlife and Natural Resources Conference* (*Transactions*) are reviewed and proofread by the Wildlife Management Institute. Unless peer review for scientific accuracy is initiated by the author(s) or by the session chair, no such detailed editorial treatment is provided or implied. Conference presentations may not be included in the *Transactions* if the written papers do not follow the prescribed guidelines or if their content is deemed to be unsuitable by the editor.

As long as supplies last, copies of the *Transactions of the 71st North American Wildlife and Natural Resources Conference* may be procured from the

WILDLIFE MANAGEMENT INSTITUTE
1146 19th Street, NW, Suite 700
Washington, DC 20036-3727
http://www.wildlifemanagementinstitute.org

The Wildlife Management Institute acknowledges special assistance at the 71st North American Wildlife and Natural Resources Conference by Matthew Dunfee, Angela Kawski, Adam Phillips and Brianne Winter.

Transactions of the 71st North American Wildlife
and Natural Resources Conference
ISSN 0078-1355

Artwork by F. L. Jaques

Printing by Sheridan Books, Inc. ✧ Ann Arbor, Michigan

Harvest Potential and Habitat Are Inextricably Linked

Michael G. Anderson
Ducks Unlimited, Canada
Stonewall, Manitoba

John M. Eadie
University of California
Davis, California

Min T. Huang
Connecticut Department of Environmental Protection
North Franklin, Connecticut

Rex Johnson
U.S. Fish and Wildlife Service
Fergus Falls, Minnesota

Mark D. Koneff
U.S. Fish and Wildlife Service
Laurel, Maryland

James K. Ringelman
Ducks Unlimited, Inc.
Bismarck, North Dakota

Michael C. Runge
U.S. Geological Survey
Laurel, Maryland

Barry C. Wilson
U.S. Fish and Wildlife Service
Lafayette, Louisiana

Introduction

The quantity and quality of habitats across the most important geographic regions for North American waterfowl are threatened by increasing human demands for water, food, energy, fiber, and residential and industrial development (North American Waterfowl Management Plan 2004). Fresh water may be the single most limiting resource for human societies in this century (Postel 1997, Gleick 2004) because of its scarcity, uneven distribution, variable quality and the complicating effects of global climate change (Gleick and Adams 2000, Burkett and Kusler 2000). For North American waterfowl, future water abundance might be most uncertain in California, the Intermountain West, the Playa Lakes and the Prairie Pothole Region (Sorenson et al. 1998, Inkley et al. 2004); although, recent evidence of wetland loss in parts of the warming Western Boreal Forest demonstrates that even this water-rich region is vulnerable to long-term change (e.g., Riordan 2005, Corcoran 2005). Moreover, the quality of water available in many aquatic systems (San Francisco Bay, Mississippi River, Illinois River, the Lower Great Lakes, Chesapeake Bay, to list a few) remains poor, and exotic invasive species of plants and benthic invertebrates are widespread.

In today's global economy, agricultural markets respond to worldwide demand for food and fiber (Brown 2004), such that improving standards of living in China, southern Asia and elsewhere will put added pressure on important waterfowl habitats like prairie grasslands and coastal plains. In the Central Valley of California, the Atlantic Coast, the Pacific Northwest and southwestern British Columbia, burgeoning human populations are encroaching rapidly on agricultural lands and marshes valuable to wintering waterfowl. And finally, rising sea levels, sometimes in combination with subsiding land, are reducing the extent of coastal marsh, especially along the Gulf of Mexico, the Mid-Atlantic states, and in Atlantic Canada (Shaw et al. 1998, Titus 1998, Najjar et al. 2000, Inkley et al. 2004). Thus, despite considerable gains in protected areas in some regions since the advent of the North American Waterfowl Management Plan (NAWMP), the challenge of sustaining or increasing the productive capacity of North America for waterfowl remains daunting. Few NAWMP joint ventures (JVs) have been able to estimate net habitat changes in their regions since the 1980s, but those that have find the results sobering. In the Atlantic Coast JV, despite the partners achieving far more than their original conservation acreage goals, Koneff and Royle (2004) estimated that approximately 6 percent of wetlands existing in the

1970s were lost by the 1990s. In Canada's Prairie Habitat JV, perennial cover important to nesting dabbling ducks increased by about 2 million acres (0.8 ha) between 1971 and 2001, but wetland losses during the same period are estimated at 2.4 to 7.6 percent (varying by province and ecoregion) and substantially offset upland gains for duck production (Devries et al. 2004). Coastal wetland losses within the Gulf Coast JV have exceeded 35 square miles (90.6 ha) per year over the last half century, and wetland restoration efforts have mitigated only a small portion of that loss (Barras et. al. 1994, B. Wilson,unpublished data).

Notwithstanding the euphoria accompanying duck population recoveries in the 1990s and a long string of liberal hunting seasons, in the next decade and beyond waterfowl managers will confront the serious challenge of reconciling our desires for waterfowl hunting in the face of multiple contravening pressures on waterfowl habitat.

Our goals for this paper are to: (a) highlight the inescapable linkages between harvest potential and the abundance and quality of waterfowl habitat, (b) explore the challenges and uncertainties around increasing or maintaining the carrying capacity of continental habitats and (c) challenge the waterfowl management community to focus more squarely on our most fundamental problem—securing the future productive capacity of waterfowl habitats.

Linkages between Harvest Management and Habitat Conservation—The NAWMP-IAFWA Joint Task Group

The waterfowl conservation community has recently engaged in an overdue discussion about the coherence of waterfowl harvest and habitat management (Johnson et al. 1997b, Williams et al. 1999, Runge et al., in press). Both habitat conservation, under the umbrella of the NAWMP, and harvest management attempt to manage populations of the same species. Both initiatives are continental in scope and depend upon feedback from monitoring and assessment to inform adaptive change. Regardless, these major programs have evolved more or less independently over the last 15 years, with little explicit recognition of their inherent codependency. As Runge et al. (in press) point out, "harvest strategy can affect whether population objectives of the plan are met, irrespective of the success of the plan's habitat conservation efforts. Conversely, habitat conservation activities under the plan can influence harvest potential and therefore the amount of hunting opportunity provided." Importantly, the plan's waterfowl population objectives can only be understood and rendered useful for conservation planning and evaluation, “if they are accompanied by an explicit specification of the harvest strategy and environmental conditions under which they are to be achieved” (Runge et al., in press).

Population goals outlined in the NAWMP have never been defined clearly in a demographic sense (Runge et al., in press). Specifically, it is unclear whether these goals are to be interpreted as carrying capacities, equilibrium population sizes assuming some level of harvest or something else. In order to properly interpret NAWMP population goals, it is necessary to specify the harvest policy (e.g., maximum sustained yield) and the environmental conditions (e.g., some specific range of uncontrolled climatic conditions) under which they are to be achieved. Present ambiguity in NAWMP population goals limits their use as performance measures and affects the utility and interpretation of regional goals, derived from continental population goals, as a basis for conservation planning. From a harvest perspective, there is additional uncertainty about the role that harvest management should play in achieving NAWMP goals and about how harvest policy should respond to future gains or losses in waterfowl habitat.

In 2005, the International Association of Fish and Wildlife Agencies (IAFWA) Adaptive Harvest Management Task Force and the NAWMP Committee commissioned the Joint Task Group (JTG) on NAWMP Goals and Harvest Management to develop options and recommendations for clarifying NAWMP population objectives and their use in harvest management. The JTG, on which several of the authors of this paper serve, is pursuing the first joint planning effort between the harvest and habitat conservation technical communities in some 20 years.

The JTG has framed the interplay between harvest and habitat management in terms of basic harvest theory as suggested by Runge et al. (in press). In brief, building on current knowledge of midcontinent mallard (*Anas platyrhynchos)* population dynamics (Runge et al. 2002, U.S. Fish and Wildlife Service 2005), it is possible to estimate a harvest yield curve for mallards that represents predicted harvest potential as a function of equilibrium population size (Figure 1, current conditions). This relationship between harvest potential and population size occurs because of density dependence in mallard recruitment or survival; that is, at higher population levels, population growth is suppressed by some form of density-related reduction in reproduction, survival or both. This particular model assumes a simple linear form of density dependence in

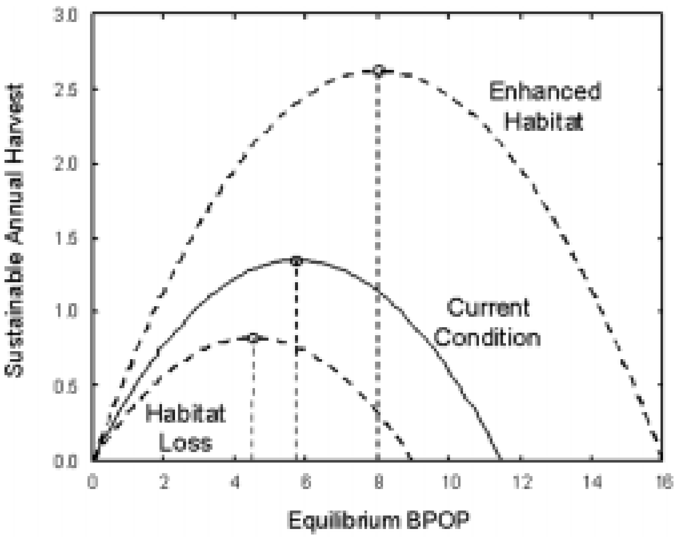

Figure 1. Sustainable annual harvest (in millions of ducks) as a function of equilibrium population size (BPOP), for midcontinent mallards under average annual water conditions. The solid curve ("Current Condition") is estimated from the 2005 AHM models, and suggests an equilibrium population size in the absence of harvest of 11.4 million. The dashed curves represent the sustainable harvest if the carrying capacity were increased to 16 million ("Enhanced Habitat"), or decreased to 9 million ("Habitat Loss"). From Runge et al. (in press).

reproduction, based on a negative relationship between the age ratio of mallards in the fall flight and the estimate of breeding population size the previous spring, adjusted for variable May pond numbers (Johnson et al. 1997a; similar evidence exists for black duck [*A. rubripes*] [Conroy et al. 2002] and northern pintail [*A. acuta*] [Runge and Boomer 2005]). Under this assumption, the harvestable surplus of birds is maximized at an intermediate population size (N_{eq}* in the notation of Runge and Johnson [2002], which is approximately *K/2*) where the balance between numbers of adult birds and production is optimal. Current models for midcontinent mallards suggest that the equilibrium population size in the absence of harvest, *K*, under average annual weather conditions, is approximately 11.4 million. We will explore uncertainties in this simple model (Figure 1) shortly. For now, the key point is this: the harvest potential of the population is strongly affected by *K*, the carrying capacity of the habitat. Future gains (Figure 1, enhanced habitat) or losses (Figure 1, habitat loss) in *K* would fundamentally affect the harvest potential of the population.

Conversely, the numbers of birds we wish to harvest, as well as the level of risk we wish to accept in regulating harvest, have direct relevance for the habitat carrying capacity that we need to provide. Preliminary modeling by the JTG suggests that *K* needed to achieve the current NAWMP goal of 8.8 million mallards would range from 8.8 million if goals are to be interpreted under a zero harvest policy (Figure 2, curve 1) to 17.9 million if goals are to be interpreted under a harvest policy that maximizes sustained yield (Figure 2, curve 2). Alternatively, if we assume a more conservative harvest policy—for example, managing for an equilibrium population size on the right shoulder of the yield curve—the average *K* required would be 11.4 to 14.4 million (Figure 2, curve 3). This simplistic representation illustrates the demographic connection between habitat and harvest management. Harvest potential and habitat capacity are most assuredly linked, and explicit recognition of this linkage is critical to the long-term success of North American waterfowl conservation and harvest regulation.

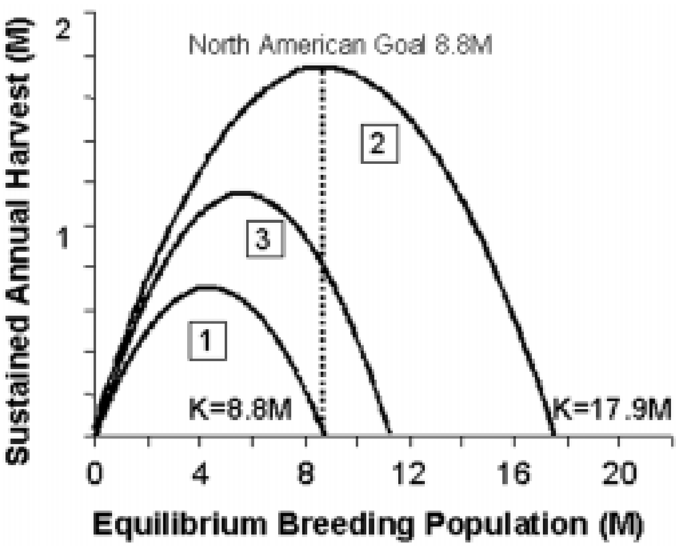

Figure 2. Plausible carrying capacity (K) required to meet the NAWMP goal of 8.8 million mallards under different harvest policies. If the NAWMP goal was interpreted under a zero-harvest policy (curve 1), the required *K* would be 8.8 million mallards. Conversely, if NAWMP goals were interpreted as being the maximum sustained yield (MSY, curve 2), the required carrying capacity would be 17.9 million mallards. Managing for an equilibrium population size on the right "shoulder' (less than MSY but greater than zero [e.g., 70 to 95 percent of MSY] curve 3) would require a carrying capacity between 11.4 to 14.4. million, depending on the location of the "shoulder point."

For waterfowl managers, the main message is simple; if we lose habitat important to waterfowl survival or recruitment, harvest potential declines. On the other hand, if we can increase or enhance habitat, the harvest potential will increase. This intuitive relationship was, of course, the foundation of the NAWMP (U.S. Department of Interior and Environment Canada 1986). Only recently, however, have we begun to quantify the tradeoffs between habitat capacity and harvest potential for midcontinent mallards. As we look ahead, the waterfowl management community will face complex choices between harvest desires and habitat realities. Whether those future actions take the form of management to enhance *K* or restrictions in harvest in the face of habitat loss, it is more clear than ever that the future of waterfowl hunting is inextricably bound to the success of the NAWMP.

The Challenge of Increasing *K*

In theory, managers might increase *K*, the equilibrium population size in the absence of harvest (Figure 1) by: (a) increasing the quantity of habitat, (b) increasing the quality of habitat or (c) increasing the annual survival rates of birds in the absence of harvest. Examples might include restoring prairie wetlands and grasslands (increasing habitat quantity), improving the quality of water reaching wetlands, substituting fall-seeded for spring-seeded cereals in northern pintail breeding areas, improving attractiveness of planted cover for mallards, restoring coastal saltmarsh or otherwise providing better winter food resources so birds return north in better condition (increasing reproductive success by improving breeding habitat quality or nonbreeding habitat quantity or quality), or managing for safer nesting sites or dispersing birds from crowded wintering sites (decreasing adult mortality).

In its forthcoming report, the JTG will demonstrate that for all three possible strategies (increase breeding habitat quantity, increase reproduction by improving habitat quality or decrease adult mortality) the observed relationship between recruitment (fall age ratios) and continental population size can be used to estimate the increase in recruitment rate needed to effect any given change in *K*. Importantly, this could provide a tool for managers to examine any number of plausible future scenarios. Note that this is a much more explicit and precise definition and use of *K* than the commonplace use of carrying capacity as a measure of food availability or the like, and understanding this difference is crucial for the use of demographic models as a basis for habitat conservation planning.

To be most efficient and effective, management interventions need to target those places and times in the annual cycle where habitat is most limiting for individual waterfowl populations. This may differ among species (e.g., Rockwell et al. 1996, Schmutz et al. 1997, Flint et al. 1998, Conroy et al. 2002, Hoekman et al. 2002) and vary over time such that those places and processes most limiting for some species or in some years will be less limiting in other circumstances. Therefore, regardless of whether a NAWMP JV is focused primarily on breeding, wintering or migration habitat, the common challenge is to weigh the empirical evidence for population limitation and to consider what might be done to affect carrying capacity (via waterfowl vital rates) in each region. Developing explicit hypotheses about limiting factors and predicted effects of conservation measures on *K* might, therefore, provide an improved framework for future JV planning and assessment.

The greatest limitation to proceeding in this manner, however, is our meager understanding of the demographic impact of habitat change, including changes associated with our conservation actions, on waterfowl population processes, both at regional and continental scales. For some species on the breeding grounds, there are well-supported estimates of the effects of various habitat conservation actions on nest densities, nest success and, in fewer cases, fledging success and recruitment (e.g., Williams et al. 1999, Garrettson and Rohwer 2001, Howerter 2002). On nonbreeding areas, it has been much more difficult to establish such linkages (Anderson et al. 1996, Johnson et al. 1997b); although, there is evidence for a few species (mallards in the Mississippi Alluvial Valley [Reinecke et al. 1987], northern pintails in central California [Fleskes et al. 2002]) that more abundant wetlands at a regional scale are associated with higher overwinter survival. Lacking an understanding of the demographic consequences of habitat management actions, many JVs have resorted to indirect measures of conservation success, such as acres conserved, duck-use days or the energetic content of available food. Improving our understanding of the effects of habitat management actions on waterfowl vital rates remains one of the most difficult and important challenges for waterfowl managers. Although we may be able to estimate in broad terms what changes in recruitment or mortality are required to achieve a certain change in carrying capacity (and thus harvest potential), we will only be successful if what we do on the ground as habitat managers truly affects vital rates. Waterfowl managers have known this for a long time, but a formal assessment framework such as that described in the forthcoming JTG report provides, for the first time, a means to more explicitly consider these relationships.

Ultimately, however, the harvest management and habitat conservation communities need to jointly agree how to balance the desire for harvest on one hand and the need for habitat conservation on the other. In our view, these choices are inextricably linked, and this connection between habitat capacity and harvest potential deserves more formal recognition and focus than it currently receives. What do we want? How much will society be willing to pay? What will other users of the land find acceptable? These are complex social questions. *The most fundamental challenge that waterfowl managers face is securing the future productive capacity of North American waterfowl habitats*. And although harvest policies that consider and help to reduce uncertainty in our understanding of population and harvest dynamics are essential, they alone cannot secure the future of waterfowling.

Key Uncertainties

The simple yield curve presented in Figure 1 was based on the weighted averages of the four alternative models presently used for midcontinent mallard adaptive harvest management (AHM) (U.S. Fish and Wildlife Service 2005). Many other forms of the yield curve are possible, however, and different forms are plausible for other species or even other populations of mallards. For instance, the form of density dependence at work in various populations could affect the shape of the yield curve. If density dependence does not act in a linear fashion over the range of observed population densities (e.g., the effect is sigmoid or linear and weak at low population densities but much stronger and nonlinear at high densities), the yield curve would not be symmetric, altering the estimates of K and $N_{eq}*$. Thus, developing a better understanding of how, during what seasons, and on what scale density dependence operates in exploited waterfowl populations is critical. While there is evidence of density dependence at some spatial scales, there remains much uncertainty about the ecological mechanisms involved. For instance, density-dependence in reproduction could be generated by crowding and population responses at a local scale, or by dispersal of some birds into poorer quality habitat regions (Dzubin 1969). This is a difficult research problem that we believe will require the cooperative effort of multiple scientists and agencies to make progress.

The yield curve in Figure 1 portrays a simple deterministic equilibrium model. Although the basic properties of this model are likely to be robust, in the real world we expect considerable stochastic variation around these equilibrium values, so that at any given time the true relationships between spring breeding population size (BPOP) and harvest potential may be better represented as a cloud of possible points around a central tendency rather than a simple line. Both sampling error and alternative plausible expressions of density dependence introduce important uncertainty into the relationships among population size, harvest potential and carrying capacity that must be acknowledged and accommodated, along with understanding of stochastic variation in both harvest and habitat management actions.

To reiterate, at regional scales (e.g., NAMWP JVs) it is urgent that we continue to improve our understanding about how habitat management actions affect population growth and its constituent vital rates. Uncertainty about these relationships increases the potential for inefficiency in the investment of limited conservation resources.

The Challenge of Allocating Conservation Efforts

Waterfowl managers will be increasingly challenged to allocate habitat conservation efforts within and among JV regions in ways that maximize the demographic impacts of habitat investments. Although there are inadequate data for most species to enable formal analyses of population sensitivities to variation in different vital rates, sufficient information is available for a few species. In midcontinent mallards, for example, changes in lambda appear to be most sensitive to changes in breeding season vital rates (nest success, duckling survival, breeding season hen survival) (Hoekman et al. 2002), but vital rates are not equally susceptible to manipulation, and the costs of affecting various vital rates may differ (Hoekman et al. 2002). Thus, a prescription cannot be as simple as, "send all of your money to the prairie pothole region." On the other hand, demographic insights do challenge all of us to invest our dollars in things that are likely to matter most. For mallards, actions that increase the productive capacity of the breeding grounds while ensuring that we do not lose ground in nonbreeding areas are consistent with our current knowledge of demography. Unfortunately, our understanding of the population dynamics and habitat limitations for other species is inadequate to make many definitive recommendations about management emphasis.

We recognize that allocating resources among geographic regions and conservation actions is a very complex matter. For one thing, demographic benefits must be evaluated against the feasibility and costs of alternative management actions. In addition, more resources are usually available for work close to the funding source than for work at distant locations. Nevertheless, the waterfowl management community needs to grapple with how waterfowl conservation dollars are invested if we are to affect carrying capacity in a meaningful way. "Business as usual" may be far from efficient. NAWMP planners envisioned 20 years ago that moving conservation resources from where most waterfowl are harvested to where most waterfowl are produced was essential.

In the near future, NAWMP partners should expand on the rudimentary modeling framework begun by the JTG to examine various scenarios for increasing *K*. Simulation studies of alternative increases (or decreases) in *K* concomitant with setting different BPOP and harvest yield objectives for those populations should be an informative place to start and contribute to the technical integration of harvest and habitat management.

Securing the Future

The simple but powerful relationships we have discussed that connect breeding population size, harvest potential and habitat carrying capacity should be used by the waterfowl management community to reconsider our goals for the future and the capacity of North American landscapes to support those goals. Armed with current knowledge of waterfowl population biology, and important technical advancements by some JVs in relating habitat conditions to vital rates, the waterfowl management community is positioned better than ever before to estimate what it will take to achieve the conservation vision of NAWMP and our harvest objectives.

Looking forward, however, the key uncertainties in these population models must be addressed as a matter of urgent importance. As we do this, we can turn our collective energies squarely toward securing the future productive capacity of North American waterfowl habitats. That is our most fundamental challenge, that is where our energies should be spent and that is what Ken Babcock and Rollie Sparrowe challenged us to do in this same forum 17 years ago.

Reference List

Anderson, M. G., M. W. Tome, R. O. Bailey, R. K. Baydack, J. W. Nelson, M. D. Koneff, R. E. Trost, T. E. Martin, J. K. Ringelman, and C. Rubec. 1996. NAWMP evaluations: How can we generate the feedback that Plan partners need? *International Waterfowl Symposium*. 7:250–7.

Babcock, K. M., and R. D. Sparrowe. 1989. Balancing expectations with reality in duck harvest management. *Transactions of the North American Wildlife and Natural Resources Conference.* 54:594–9.

Barras, J. A., P. E. Bourgeois, and L. R. Handley. 1994. *Land loss in coastal Louisiana 1956-90, Open-File Report 94-01*. Lafayette, Louisiana: National Biological Survey, National Wetlands Research Center.

Boesch, D. F., J. C. Field, and D. Scavia, Eds. 2000. *The potential consequences of climate variability and change on coastal areas and marine resources: Report of the Coastal Areas and marine resources sector team, U.S. National Assessment of the potential consequences of climate variability and change, Coastal Ocean Program Decision Analysis Series No. 21.* Silver Spring, Maryland: U.S. Global Change Research Program, National Oceanic and Atmospheric Administrtion, Coastal Ocean Program Decision Analysis Series No. 21. NOAA Coastal Ocean Program.

Brown, L. 2004. *Outgrowing the Earth*. New York, New York: W. W. Norton and Company.

Burkett, V., and J. Kusler. 2000. Climate change: Potential impacts and interactions in wetlands of the United States. *Journal of the American Water Resources Association*. 36:313–20.

Conroy, M. J., M. W. Miller, and J. E. Hines. 2002. Identification and synthetic modeling of factors affecting American black duck populations. *Wildlife Monographs*. 150:1–64.

Cooch, E. G., R. F. Rockwell, and S. Brault. 2001. Retrospective analysis of demographic responses to environmental change: An example in the lesser snow goose. *Ecological Monographs*. 71:377–400.

Corcoran, R. M. 2005. *Lesser scaup nesting ecology in relation to water chemistry and macroinvertebrates on the Yukon Flats, Alask*a. M.S. thesis, Department of Zoology and Physiology, University of Wyoming, Laramie.

Devries, J. H., K. L. Guyn, R. G. Clark, M. G. Anderson, D. Caswell, S. K. Davis, G. McMaster, T. Sopuck, and D. Kay. 2004. *Prairie Habitat Joint Venture (PHJV) waterfowl habitat hoals update: Phase I*. Edmonton, Alberta: Prairie Habitat Joint Venture, Environment Canada.

Dzubin, A. 1969. Comments on carrying capacity of small ponds for ducks and possible effects of density on mallard production, Saskatoon Wetlands Seminar. *Canadian Wildlife Service Report Series*. 6:138–60.

Fleskes, J. P., R. L. Jarvis, and D. S. Gilmer. 2002. September-March survival of female northern pintails radiotagged in the San Joaquin Valley, California. *Journal of Wildlife Management*. 66:901–11.

Flint, P. L., J. B. Grand, and R. F. Rockwell. 1998. A model of northern pintail productivity and population growth rate. *Journal of Wildlife Management*. 62:1,110–8.

Garrettson, P. R., and F. C. Rohwer. 2001. Effects of mammalian predator removal on production of upland nesting ducks in North Dakota. *Journal of Wildlife Management*. 65:398–405.

Gleick, P. H., ed. 2004. *The world's water 2004–2005: The biennial report on freshwater resources*. Covello, California: Island Press.

Gleick, P. H., and D. B. Adams. 2000. Water: The potential consequences of climate variability and change for the water resources of the United States. In *The report of the water sector assessment team of the national assessment of the potential consequences of climate variability and change.* Oakland, California: Pacific Institute for Studies in Development, Environment and Security.

Hoekman, S. T., L. S. Mills, D. W. Howerter, J. H. Devries, and I. J. Ball. 2002. Sensitivity analyses of the life cycle of midcontinent mallards. *Journal of Wildlife Management*. 66:883–900.

Howerter, D. W. 2002. *Factors affecting duck nesting density in the aspen parkland: A spatial analysis*. Ph.D. dissertation, Department of Ecology, Montana State University, Bozeman, Montana.

Inkley, D. B., M. G. Anderson, A. R. Blaustein, V. R. Burkett, B. Felzer, B. Griffith, J. Price, and T. L. Root. 2004. Global climate change and wildlife in North America. In *The Wildlife Society technical review*, 04-2. Bethesda, Maryland: The Wildlife Society.

Johnson, F. A., C. T. Moore, W. L. Kendall, J. A. Dubovsky, D. F. Caithamer, J. R. Kelley, Jr., and B. K. Williams. 1997a. Uncertainty and the management of mallard harvests. *Journal of Wildlife Management*. 61:202–16.

Johnson, F. J., M. G. Anderson, R. K. Baydack, J. W. Nelson, J. K. Ringelman, M. D. Koneff, R. O. Bailey, T. E. Martin, and C. Rubec. 1997b. Enhancing biological performance of the North American Waterfowl Management Plan. *Transactions of the North American Wildlife and Natural Resources Conference*. 62:377–85.

Koneff, M. D., and J. A. Royle. 2004. Modeling wetland change along the United States Atlantic Coast. *Ecological Modeling*. 177:41–59.

Najjar, R. G., H. A. Walker, P. J. Anderson, E. J. Barron, R. J. Bord, J. R. Gibson, V. S. Kennedy, C. G. Knight, J. P. Megonigal, R. E. O'Connor, C. D. Polsky, N. P. Psuty, B. A. Richards, L. G. Sorenson, E. M. Steele, and R. S. Swanson. 2000. The potential impacts of climate change on the mid-Atlantic coastal region. *Climate Research*. 14:219–33.

North American Waterfowl Management Plan Committee. 2004. *North American waterfowl management plan 2004. Implementation framework: Strengthening the biological foundation*. Canadian Wildlife Service, U.S. Fish and Wildlife Service, Secretaria de Medio Ambiente y Recursos Naturales.

Postel, S. 1997. *Last oasis: Facing water scarcity*. New York, New York: W.W. Norton and Company.

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* 52:258–63.

Riordan, B. 2005. *Using remote sensing to examine changes of closed-basin surface water area in interior Alaska from 1950–2002*. M. S. thesis, Department of Resources Management, University of Alaska, Fairbanks, Alaska.

Rockwell, R., E. Cooch, and S. Brault. 1996. Dynamics of the mid-continent population of lesser snow geese—Projected impacts of reductions in survival and fertility on population growth rates. In *Arctic ecosystems in peril: Report of the Arctic Goose Habitat Working Group*, ed. B. D. J. Batt, 73–100. Arctic Goose Joint Venture special publication. Washington, DC and Ottawa, Ontario: U.S. Fish and Wildlife Service and Canadian Wildlife Service.

Runge, M. C., and G. S. Boomer. 2005. *Population dynamics and harvest management of the continental northern pintail population. (Final*

Report, June 6, 2005). U.S. Geological Survey, Patuxent Wildlife Research Center. http://www.fws.gov/migratorybirds/reports/ahm05/NOPI%202005%20Report%202.pdf.

Runge, M. C., and F. A. Johnson. 2002. The importance of functional form in optimal control solutions of problems in population dynamics. *Ecology*. 83:1,357–71.

Runge, M.C., F. A. Johnson, M.G. Anderson, M.D. Koneff, E. T. Reed, and S. E. Mott. In press. The need for coherence in waterfowl harvest and habitat management. *Wildlife Society Bulletin.*

Runge, M. C., F. A. Johnson, J. A. Dubovsky, W. L. Kendall, J. Lawrence, and J. Gammonley. 2002. *A revised protocol for the adaptive harvest management of mid-continent mallards. (Final Report, June 17, 2002).* U.S. Fish and Wildlife Service, Division of Migratory Bird Management. http://www.fws.gov/migratorybirds/reports/ahm02/MCMrevise2002.pdf.

Schmutz, J. A., R. F. Rockwell, and M. R. Petersen**.** 1997. Relative effects of survival and reproduction on the population dynamics of emperor geese. *Journal of Wildlife Management*. 61:191–201.

Shaw, J., R. B. Taylor, S. Solomon, H. A. Christian, and D. L. Forbes. 1998. Potential impacts of global sea-level rise on Canadian coasts. *Canadian Geographer.* 42:365–79.

Sorenson, L. G., R. Goldberg, T. L. Root, and M. G. Anderson. 1998. Potential effects of global warming on waterfowl populations breeding in the Northern Great Plains. *Climatic Change*. 40:343–69.

Titus, J. G. 1998. Rising seas, coastal erosion and the takings clause: How to save wetlands and beaches without hurting property owners. *Maryland Law Review.* 57:1,279–399.

U. S. Department of the Interior and Environment Canada. 1986. *The North American Waterfowl Management Plan.* Washington, DC: U.S. Fish and Wildlife Service.

U.S. Fish and Wildlife Service. 2005. *Adaptive harvest management: 2005 duck hunting season*. Washington, DC: U.S. Department of Interior.

Williams, B. K., M. D. Koneff and D. A. Smith. 1999. Evaluation of waterfowl conservation under the North American Waterfowl Management Plan. *Journal of Wildlife Management.* 63:417–40.