5-2002

Factors Affecting the Harvest Vulnerability of Trumpeter Swans

Heidi L. Tangermann
Utah State University

FACTORS AFFECTING THE HARVEST VULNERABILITY

OF TRUMPETER SWANS

by

Heidi L. Tangermann

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Wildlife Ecology

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

2002

ABSTRACT

Factors Affecting the Harvest Vulnerability of Trumpeter Swans

by

Heidi L. Tangermann, Master of Science

Utah State University, 2002

Major Professor: Terry A. Messmer
Department: Fisheries and Wildlife

Two species of swan are regularly found in Utah, tundra swans (*Cygnus columbianus*) and trumpeter swans (*Cygnus buccinator*). Tundra swans migrate through Utah. During the fall migration period they are hunted in the state under guidelines established by the United States Fish and Wildlife Service (USFWS). Trumpeter swans are occasional visitors to Utah during the same migration period. Because trumpeter swans are difficult to distinguish from tundra swans in flight, they are at risk of being harvested during the swan hunt. In my thesis, I examine the factors that may influence trumpeter swan vulnerability to harvest. Specifically, I evaluated height and velocity of foraging flights for both species of swans and identified characteristics of Utah swan hunters. This information could assist the Utah Division of Wildlife Resources in developing an educational program to reduce trumpeter swan vulnerability.

I applied flight dynamics theory to 86 trumpeter and 178 tundra swan measurements. Both speed and height of short-range foraging flights were used to predict trumpeter and tundra swan vulnerability. The theory predicted that trumpeter swans fly slower and lower than tundra swans, and thus may be more vulnerable to harvest. The predicted flight height of tundra swans was compared to observations of tundra swans made at the USFWS Bear River Migratory Bird Refuge. Average body area of the two species of swans was compared. Trumpeter swans had, on average, a 30% larger body area. Combining the lower predicted flight and larger body size, trumpeter swans may be up to 26% more vulnerable on a 3.8-km flight and 15% more vulnerable on a 10-km flight than tundra swans on the same flight path.

In addition to current regulations, the Utah Division of Wildlife Resources is interested in implementing a swan hunter education course to further reduce the likelihood of a trumpeter swan being harvested during the swan hunt. I surveyed a representative sample of Utah swan hunters to determine if they would participate in the course and attitudes about current regulations, and to identify specific topics that should be emphasized in the course. My survey suggested that Utah swan hunters would be receptive to a swan hunter education course. Based on the responses, any swan hunter education course should emphasize identification of trumpeter and tundra swans, distance estimation, and regulations regarding the swan hunt.

(96 pages)

ACKNOWLEDGMENTS

Funding for this project was provided by the Utah State University Vice President for Research under the Community/ University Research Initiative (CURI), the Utah Division of Wildlife Resources, and the United States Fish and Wildlife Service. The Bear River Migratory Bird Refuge and the Bear River Club Company provided access to study sites. The Jack H. Berryman Institute provided funding for conferences and equipment.

Special thanks to my advisor, Terry Messmer, for his support and guidance throughout this process, and to Jim Powell, without whom none of this would have been possible. I also thank Michael Conover for his valuable input and advice on this thesis. This project has also benefited from discussions with Adele Cutler, Richard Krannich, John Bissonette, and Tami Pearl.

The cooperation of state and federal agencies, as well as private organizations, in this project was a great help. Thanks to Tom Aldrich for equipment and advice throughout all stages of this project. Thanks to the Bear River Migratory Bird Refuge staff for advice and equipment. Thanks to numerous volunteers who were willing to monitor check stations. Trumpeter swan measurements could not have been obtained without the help of the following: the Trumpeter Swan Society, Martha Jordan, Rachel Vaughn, Laurel Degernes, Craig Whitman of Harriman State Park, the Idaho Department of Fish and Game, and Bill Long of the Wyoming Wetland Society.

Finally, thanks to my parents who never cease to encourage me in all I do and thanks to David Plank and Astro for keeping me sane through this whole process.

Heidi L. Tangermann

CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure | Page

CHAPTER 1

LITERATURE REVIEW

Introduction

Three species of swans regularly occur in North America, mute swans (*Cygnus olor*), trumpeter swans (*Cygnus buccinator*), and tundra swans (*Cygnus columbianus).* Of these species, only the trumpeter and tundra swans are native to North America. Mute swans were brought to the U.S. from Eurasia in the early 1900s. The first birds either escaped from captivity or were purposely released. Currently, there are an estimated 7,000 free-ranging mute swans in the U.S. These birds occur mainly on the East Coast and around the Great Lakes and are rare visitors to the Western States (Bellrose 1976, United States Fish and Wildlife Service 2000).

Trumpeter swans were once widespread throughout North America (Figure 1.1). Breeding populations occurred throughout central and western Canada and Alaska, and across the U.S. from Oregon to the Carolinas. Trumpeters wintered in the Chesapeake Bay, along the Mississippi Valley to the Central Valley of California (Mitchell 1994, Phillips 1911).

Swan-skins were highly desirable in the fur trade. The Hudson Bay Company sold more than 17,000 swan-skins between 1853 and 1877, most of which were trumpeters. By the turn of the century trumpeter swans had been hunted nearly to extinction (Banko 1960). Trumpeters were probably more vulnerable to harvest than tundra swans because their breeding areas tended to be further south and thus they were more accessible to early fur traders and settlers. In the early 1900s, many biologists believed it was only a matter of time before trumpeter swans went extinct. In 1935, the only known population of trumpeter swans consisted of a small group of 65 in the tri-state area of Idaho, Montana, and Wyoming. Red Rock Lakes National Wildlife Refuge in Montana was established at this time to protect vital trumpeter swan breeding grounds. Due in large part to establishment of this refuge, the number of trumpeters in this area increased to 600 by 1954. Other groups were discovered later, including a flock of about 100 trumpeters in the Grand Prairie area of Alberta and another flock of about 200 on the Kenai Peninsula of Alaska (Coale 1915, Banko 1960, Bent 1962).

Currently there are three populations of trumpeter swans, the Pacific Coast (PCP), the Rocky Mountain (RMP), and the Interior (Figure 1.1). These populations are separated for management purposes and are not considered genetically distinct (Barrett and Vyse 1982, United States Fish and Wildlife Service 2000). The PCP nests in Alaska and typically winters along the Pacific Coast on the southeast region of Alaska, the coast of British Columbia, and occasionally as far south as California. The RMP is comprised of a migratory flock that breeds in Canada and a resident flock that does not leave the tri-state area. The Interior population is comprised of a few flocks of trumpeter swans throughout the Midwest (Gillette and Shea 1995, Banko and Mackay 1964). The entire trumpeter swan population in North America is estimated at 19,000 birds (United States Fish and Wildlife Service 2000).

Like the trumpeter swan, tundra swan populations also declined in the mid-1800s. Because their breeding grounds were largely unexplored by hunters and trappers, the population declines observed were not as severe (Figure 1.2). Tundra swans breed along the coast, usually in river deltas, from Alaska to the eastern region of the Hudson Bay (Bellrose 1976, Limpert and Earnst 1994). For management purposes the tundra swan has been separated into Eastern and Western populations. The Western population breeds in Alaska and part of the Yukon Territory and winters on the Pacific Coast from Vancouver to Central California, and inland in British Columbia, Oregon, Nevada, Utah, Idaho, and Montana. The Eastern population nests between the eastern side of the Yukon Territory and the eastern side of the Hudson Bay, and winters on the Atlantic coast primarily between New Jersey and South Carolina. Large numbers of tundra swans also winter in the Chesapeake Bay area. Smaller numbers winter in the Great Lakes area, in Pennsylvania along the lower Susqehanna River (Sladen 1973, Limpert and Earnst 1994), and occasionally as far south as interior Mexico (Drewien and Benning 1997). The tundra swan population in North America is estimated at 120,000 birds (United States Fish and Wildlife Service 2000).

Migration and Habitat Use

Tundra swans of the western population generally leave their breeding grounds in September and begin arriving in Utah in late October. In Utah many rest and feed at the United States Fish and Wildlife Service (USFWS) Bear River Migratory Bird

Refuge (BRMBR) in November and December, with smaller groups scattered among the state waterfowl management areas along the eastern shore of the Great Salt Lake. A majority of these tundra swans then make another long flight across the Great Basin to the Stillwater Refuge in western Nevada, and then on to California where they spend the remainder of the winter (Limpert and Earnst 1994, Roy 1995). Trumpeter swans from the RMP leave their breeding grounds in mid-October to late November, and make a series of shorter flights to reach their tri-state wintering area (Squires 1991, Mitchell 1994, Engelhardt 1997).

Trumpeter and tundra swans tend to have different habitat preferences. Trumpeter swans generally use smaller ponds and slightly deeper waters than tundra swans (Engelhardt 1997, Earnst 1994, Peliazza 2000).

Current Management and Population Status

Tundra swan populations have been steadily increasing since protection under the Migratory Bird Treaty Act of 1918. In the western U.S. tundra swan populations have increased to levels that enabled the USFWS to implement experimental hunts. The first regulated swan hunt was conducted in Utah during 1962. In 2001, the Utah Division of Wildlife Resources (UDWR) issued 2000 tundra swan permits. Nevada implemented a tundra swan hunt in 1969 and Montana in 1970 (Drewien et al. 1999). In 1984, the USFWS implemented regulations to permit hunting of the eastern tundra swan population. Currently New Jersey, North Dakota, South Dakota, North Carolina, Virginia, and Alaska conduct tundra swan hunts (Luszcz and Betsill 1988, Bartonek et al. 1991, Serie and Bartonek 1991).

Since protection, the population of trumpeter swans has also been steadily increasing. However, the status of the RMP is still questionable because the entire population winters in the tri-state area of Montana, Idaho, and Wyoming. Trumpeter swans were supplementally fed at Red Rocks Lakes National Wildlife Refuge from its establishment in 1935 to 1992 (Subcommittee on the Rocky Mountain Trumpeter Swans 1998). This was initially done to discourage migration to wintering sites in eastern Idaho, where it was feared the swans would be illegally hunted. However, as a result of the feeding operations, the swans' learned migration behavior has apparently been lost. Consequently, the entire RMP winters in a small area that may not be able to support additional birds. Any additional population increase in these areas may exacerbate habitat deterioration. Thus, the entire RMP is believed to be at increased risk of collapse because of disease or severe weather, which could be magnified by poor winter habitat conditions (Gillette and Shea 1995, Reiswig and Mitchell 1995).

Although some trumpeter swans have been successfully relocated to other wintering areas, large-scale migratory behavior has not been reestablished. The possibility of creating a migratory pathway through the Great Salt Lake Basin in Utah and on to the Central Valley of California has been investigated. The majority of the Western population of tundra swans currently uses this route, and it may be feasible for trumpeter swans to follow this well-established migration corridor. It has been suggested that trumpeter swans be reintroduced in Utah to encourage the establishment of this migratory pathway (Engelhardt 1997, Shea and Drewien 1999).

A major concern regarding the reintroduction of trumpeter swans into Utah is their vulnerability to harvest during the swan hunting season. It is legal for hunters to take either tundra or trumpeter swans during this swan season. If 10 trumpeters are harvested, the swan hunting season in Utah closes for the remainder of the year (Utah Division of Wildlife Resources 2001). This regulation was implemented because of the difficulty hunters in the field may have in distinguishing the difference between trumpeter and tundra swans. The UDWR requires that all swan hunters have their harvested swans checked by state or federal officials to determine the species. The UDWR believes that by legally allowing some trumpeter swans to be harvested, hunters will be less likely to conceal birds they may believe to be trumpeters. The UDWR is interested in sustaining the swan hunt because it is popular, and because the hunt has not precluded population growth (Tessmann 2000). However, they also wish to address the concerns of trumpeter swan restoration advocates. To accomplish these goals, the UDWR needs information regarding factors that affect the relative vulnerability of the two species, including flight characteristics and hunter behavior.

Relationship of Hunter Characteristics to Management

The question of swan vulnerability to hunting is a major conservation issue in Utah and surrounding states (United States Fish and Wildlife Service 2000). The primary reason for this concern is that trumpeter swans are not easily distinguished in flight from tundra swans (Patten and Heindel 1994). Additionally, little or no information is available on the relative vulnerability of the two species. In particular, are trumpeter swans more vulnerable to hunting than tundra swans because of species-specific flight trajectories? If trumpeter swans are more vulnerable due to flight characteristics, then it may be possible to develop an educational course for Utah swan hunters to make them aware of these differences and further reduce the potential risk to trumpeter swans.

Little information regarding the characteristics of swan hunters exists for the development of this education course. The only published survey on swan hunters was conducted in North Carolina by Luszcz and Betsill (1988). They monitored the tundra swan hunt to determine hunter success, effort, and performance. However, they did not identify specific characteristics that could be used to develop a swan hunter education course. State and federal wildlife agencies have used hunter surveys to develop regulations or implement programs designed to achieve public wildlife conservation objectives.

Langenau and Mellon (1980) summarized hunting habits of young hunters in Michigan, including where they hunted, what they hunted, and success rate in an effort to determine the characteristics of future, older age classes of hunters in the state. The information gathered in the study was used to predict future trends of the hunting population for those who start hunting at an early age. The research identified specific programs that could be implemented to recruit and retain hunters of different age groups.

Gratson and Whitman (2000) surveyed elk hunters to determine their characteristics, hunting experiences and opinions regarding road closure regulations. This information was used to determine characteristics of hunters using specific areas. They discovered that hunters generally supported the use of road closures as a management tool, while residents who had hunted elk longer were more likely to oppose the road closure decisions. The study identified the need for educational programs to explain the benefits of road closures to resident elk hunters.

Dahlgren et al. (1977) looked at the relationship between the level of understanding of wildlife principles and other characteristics of the Iowa general public. Their results suggested that educational programs should include contact with wildlife in a natural setting, as this was positively correlated with understanding of wildlife principles. Students tended to have an unfavorable attitude toward hunting, suggesting a growing trend toward an anti-hunting attitude; the authors suggested focusing on improving the quality of hunting and on non-hunting aspects of wildlife management.

Nieman et al. (1987) compared hunter observations to bag checks at check stations and interviews conducted with hunters to determine the hunters' identification skills, species taken by hunters, crippling losses, and hunting regulation violations. Their study showed that most hunters shot at any duck or goose within range, even in regions where species-specific regulations were in effect. Bag limits during the time of the study were much higher than what the average hunter could achieve and violations of wildlife laws were numerous. The authors suggested that lowering the bag limits would reduce hunting violations and crippling losses. They also suggested that species-specific regulations were not likely to be effective as most of the hunters were not selective in what they harvested and were generally not skilled in identifying waterfowl. These studies demonstrate how human dimensions information can be used to achieve management objectives.

Flight Dynamics Theory

The flight dynamics theory has been used to predict optimal trajectories for foraging, and migration flights of birds could also prove useful to determine trumpeter swan vulnerability to hunting. Pennycuick (1989) presented an approach to estimating power requirements for level, long-distance flight and for predicting speeds at which birds can be expected to fly at differing altitudes.

Pennycuick (1989) identified two potential flight speeds that can be calculated for birds: minimum power speed, at which the bird requires the least power to fly, and maximum range speed, the speed at which the ratio of power to speed is least. Though the maximum range speed requires more power, it minimizes the energy required per unit distance flown.

Following Pennycuick (1989), the mechanical power requirements for a bird's powered flight can be written mathematically as:

$$P(V) = R\left(P_{met} + \frac{C_{ind}}{\rho V} + \frac{C_{pro}}{\sqrt{\rho}} + C_{par}\,\rho V^3\right)$$

.

Here V is the velocity of the bird in level flight, ρ is the density of air, R accounts for respiratory overhead, P_{met} is the basal metabolic power requirement, and C_* are parameters related to *ind*uced, *pro*file and *par*asite power requirements. This description of energy consumption per unit time includes: the effects of metabolic requirements (both basal metabolism and the effect of increasing aerobic respiration under increasing speeds), the power required for lift (induced power), and the drag caused by both wings (profile power) and body (parasite power). The actual energetic cost to the swan is higher by a factor of 4.35 due to the inefficiency of converting fat to mechanical energy. The energetic cost is further elevated if any portion of the flight requires anaerobic respiration. Known flight parameters (Powell and Engelhardt 2000) are explained in Table 1.1.

Each of the parameters P_{met}, C_{ind}, C_{pro}, and C_{par} also depends on physical measurements of the swan; in particular, the cross-sectional body area (A_b), wingspan, and mass of the bird must be known. Given these measurements, it is possible to calculate the most efficient speed for a particular bird to cover a large distance. This defines the maximum-range speed (V_{mr}).

Where the issue is energy cost for short-distance flights, the power required for take-off and climbing to altitude must also be accounted for (Powell and Engelhardt 2000). Additional observations to determine the time required for take-off (T_{to}) and take-off efficiency (C_{eff}) must be collected. Knowing these two parameters, the energetic cost of short distance flights can be calculated. The total energy required for flight at speed V over a distance L is:

$$E_{short}(V) = R\left[C_{eff}\left(\frac{1}{4}C_{par}\rho V^3 T_{to} + \frac{1}{2}mV^2\right) + \frac{L}{V}\left\{P_{met} + \frac{C_{ind}}{\rho V} + \frac{C_{pro}}{\sqrt{\rho}} + C_{par}\rho V^3\right\}\right]$$

The optimal velocity for a swan to traverse a known distance, L (in meters), is then given by the minimum of E_{short}. Peak altitude, *H* (in meters), on an optimal trajectory can also be determined:

$$H = 100\left(\frac{L^2}{8\rho}\right)\left(\frac{C_{ind} + \frac{1}{2}C_{pro}\sqrt{\rho}\,V - C_{par}\rho^2 V^4}{C_{ind} - 3\,C_{par}\rho^2 V^4}\right)$$

This predicted altitude, *H*, can then be used to help assess relative vulnerability to hunting. Powell and Engelhardt (2000) expanded on that theory to include nontrivial costs for take-off and savings associated with climbing into less-dense air. They were then able to use calculus of variations to determine theoretical flight profiles, which gave minimum energy consumption for short-distance foraging flights. Powell and Engelhardt (2000) also compared the theoretical predictions with actual data on tundra swans collected in the BRMBR, thus providing some validation for the optimal theory.

Flight dynamics research of foraging flights is limited. Pennycuick and deSanto (1989), in a study of white ibis (*Eudocumus albus*), estimated a maximum range speed of 18.8 m/sec for females and 19.8 m/sec for males. Observed flight speeds were an average of 13.1 m/sec. Pennycuick and deSanto (1989) speculated that these birds could be flying slower than expected in order to look for potential foraging sites.

Bryan et al. (1995) followed wood storks (*Mycteria americana*) from roosting to feeding sites and observed flight speeds of 12.8 m/sec for flapping flight and 9.5 m/sec for soaring flight. Using Pennycuick's (1989) model, predicted maximum range flight speed was 19.7 m/sec, and a minimum power speed of 12.1 m/sec, indicating that these birds fly at minimum power instead of maximum efficiency. However, the estimates were based on the measurements of one bird.

Purpose

In this thesis I examined height and velocity for foraging flights of trumpeter swans and tundra swans, and conducted human dimensions research to determine the characteristics of swan hunters in Utah. The flight dynamics research will enhance conservation of migratory trumpeter swans by increasing managers' and hunters' awareness of the relationship between flight parameters and the issue of swan vulnerability to hunting. I used predicted optimal flight trajectories to determine the vulnerability of trumpeter swans to hunting in relation to flight velocities, the altitude flown between resting and foraging areas, and hunter strategies. Flight energetics models were parameterized and applied to tundra and trumpeter swans in Chapter 2 to help determine the vulnerability of trumpeter swans in Utah to harvest during foraging and refueling at the BRMBR.

The human dimensions research presented in Chapter 3 will provide the UDWR with new information regarding swan hunters which could then be used to develop educational programs and new regulations to further reduce the risk of harvesting a trumpeter swan during the tundra swan season. In addition, this educational effort may help resolve long standing conflicts over the recovery of the RMP trumpeter swans and the role of Utah in this process.

Style

The Abstract, Acknowledgements, Contents, and Chapters 1, 3, and 4 are written using the editorial guidelines of the Wildlife Society Bulletin. Chapter 2 is written using the editorial guidelines of the Auk.

Literature Cited

Banko, W. E. 1960. The trumpeter swan: its history, habits, and population in the United States. United States Fish and Wildlife Service, Washington, D.C., USA.

Banko, W. E., and R. H. Mackay. 1964. Our native swans. Pages 155-164 *in* J. P. Linduska, editor. Waterfowl tomorrow. United States Fish and Wildlife Service, Washington, D.C., USA.

Barrett, V. A., and E. R. Vyse. 1982. Comparative genetics of three trumpeter swan populations. Auk 99:103-108.

Bartonek, J. C., J. R. Serie, and K. A. Converse. 1991. Mortality in tundra swans. Pages 356-358 *in* J. Sears and P. J. Bacon, editors. Proceedings of the 3rd International Waterfowl and Wetlands Research Bureau, International Swan Symposium. Wildlfowl Supplement Number 1. Slimbridge, England.

Bellrose, F. C. 1976. Ducks geese and swans of North America. Second edition. Stackpole Books, Harrisburg, Pennsylvania, USA.

Bent, C. 1962. Life histories of North American wildfowl: Part 2. Dover Publications, New York, New York, USA.

Bryan, A. L. Jr., M. C. Coulter, and C. J. Pennycuick. 1995. Foraging strategies and energetic costs of foraging flights by breeding wood storks. Condor 97:133-140.

Coale, H. K. 1915. The present status of the trumpeter swan (*Olor buccinator*). Auk 32:82-90.

Dahlgren, R. B., A. Wywialowski, T. A. Bubolz, and V. L. Wright. 1977. Influence of knowledge of wildlife management principles on behavior and attitudes toward resource issues. Transactions of the North American Wildlife and Natural Resources Conference 42:146-155.

Drewien, R. C., and D. S. Benning. 1997. Status of tundra swans and trumpeter swans in Mexico. Wilson Bulletin 109:693-701.

Drewien, R. C., J. T. Herbert, T. W. Aldrich, and S. H. Bouffard. 1999. Detecting trumpeter swans harvested in tundra swan hunts. Wildlife Society Bulletin 27:95-102.

Earnst, S. L. 1994. Tundra swan habitat preferences during migration in North Dakota. Journal of Wildlife Management 58:546-551.

Engelhardt, K. A. M. 1997. Evaluation of translocation criteria for trumpeter swans reintroduced to northern Utah: habitat quality and interactions with tundra swans. Thesis, Utah State University, Logan, Utah, USA.

Gillette, L. N., and R. Shea. 1995. An evaluation of trumpeter swan management today and a vision for the future. Transactions of the North American Wildlife and Natural Resources Conference 60:258-265.

Gratson, M. W., and C. Whitman. 2000. Characteristics of Idaho elk hunters relative to road access on public lands. Wildlife Society Bulletin 28:1016-1022.

Langenau, E. E. Jr., and P. M. Mellon. 1980. Characteristics and behaviors of Michigan 12- to 18-year-old hunters. Journal of Wildlife Management 40:69-78.

Limpert, R. J., and S. L. Earnst. 1994. Tundra swan (*Cygnus columbianus*). The birds of North America, Number 89, A. Poole, and F. Gill, editors. The American Ornithologists' Union, Washington, D.C., USA, and the Academy of Natural Sciences, Philadelphia, Pennsylvania, USA.

Luszcz, D., and C. Betsill. 1988. Evaluation of a tundra swan season in North Carolina. Proceedings of the Annual Conference of the Southeast Association of Fish and Wildlife Agencies 42:388-395.

Mitchell, C. D. 1994. Trumpeter swan (*Cygnus buccinator*). The birds of North America, Number 105, A. Poole, and F. Gill, editors. The American Ornithologists' Union, Washington, D.C., USA, and the Academy of Natural Sciences, Philadelphia, Pennsylvania, USA.

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

Patten, M. A., and M. T. Heindel. 1994. Identifying trumpeter and tundra swans. Birding 26:306-318.

Pelizza, C. A. 2000. Winter site selection characteristics, genetic composition and mortality factors of the high plains flock of trumpeter swans. Pages 29-34 *in* R. Shea, M. H. Linck, and H. K. Nelson, editors. Proceedings and papers of the 17th Trumpeter Swan Society Conference. The Trumpeter Swan Society, Maple Plain, Minnesota, USA.

Pennycuick, C. J. 1989. Bird flight performance: a practical calculation manual. Oxford University Press, Oxford, England.

Pennycuick, C. J., and T. deSanto. 1989. Flight speeds and energy requirements for white ibises on foraging flights. Auk 106:141-144.

Phillips, J. C. 1911. A years collecting in the state of Tamaulipas, Mexico. Auk 28:67-89.

Powell, J. A., and K. A. M. Engelhardt. 2000. Optimal trajectories for the short-distance foraging flights of swans. Journal of Theoretical Biology 204:415-430.

Roy, V. 1995. Trumpeter and tundra swans: their history and future at the Bear River Migratory Bird Refuge. Pages 53-58 *in* M. H. Linck and D. C. Compton, editors. Proceedings and papers of the 15th Trumpeter Swan Society Conference. The Trumpeter Swan Society, Maple Plain, Minnesota, USA.

Reiswig, B., and C. D. Mitchell. 1995. Rocky Mountain population of trumpeter swans: status, trends, problems, outlook. Pages 9-11 *in* M. H. Linck and D. C. Compton, editors. Proceedings and papers of the 15th Trumpeter Swan Society Conference. The Trumpeter Swan Society, Maple Plain, Minnesota, USA.

Serie, J. R., and J. C. Bartonek. 1991. Harvest management of tundra swans *Cygnus columbianus* in North America. Pages 359-367 *in* J. Sears and P. J. Bacon, editors. Proceedings of the 3rd International Waterfowl and Wetlands Research Bureau, International Swan Symposium. Wildfowl Supplement Number 1. Slimbridge, England.

Shea, R. E., and R. C. Drewien. 1999. Evaluation of efforts to redistribute the Rocky Mountain population of trumpeter swans 1986-97. Department of Biological Sciences, Idaho State University, Pocatello, Idaho, USA.

Sladen, W. L. 1973. A continental study of whistling swans using neck collars. Wildfowl 24:8-14.

Squires, J. R. 1991. Trumpeter swan food habits, forage processing, activities, and habitat use. Dissertation, University of Wyoming, Laramie, Wyoming, USA.

Subcommittee on the Rocky Mountain Trumpeter Swans. 1998. Pacific flyway management plan for the Rocky Mountain population of trumpeter swans. Pacific Flyway Study Committee, Portland, Oregon, USA.

Tessmann, S. A. 2000. Pacific flyway committee perspective on RMP trumpeter swan restoration. Pages 67-73 *in* R. E. Shea, M. H. Linck and H. K. Nelson, editors. Proceedings and papers of the 17th Trumpeter Swan Society Conference. The Trumpeter Swan Society, Maple Plain, Minnesota, USA.

United States Fish and Wildlife Service. 2000. Proposal to establish operational general swan hunting seasons in the pacific flyway. Environmental Assessment. United States Department of Interior, Washington, D.C., USA.

Utah Division of Wildlife Resources. 2001. 2001-2002 Utah waterfowl proclamation. Department of Natural Resources, Salt Lake City, Utah, USA.

Table 1.1. Parameters used in calculation of predicted swan height and velocity of flight.

Parameter[a]	Description	Value
ρ	Density of Air	1.06kg/m^3 at 1500 m
g	Acceleration due to gravity	9.81 m/sec^2
K_i	Coefficient of induced power	~1.1
K_p	Coefficient of profile power	~0.97
R	Respiratory power overhead rate fraction	~1.1
C_{Db}	Coefficient of drag for body	0.25 (swan)

[a] Powell and Engelhardt (2000)

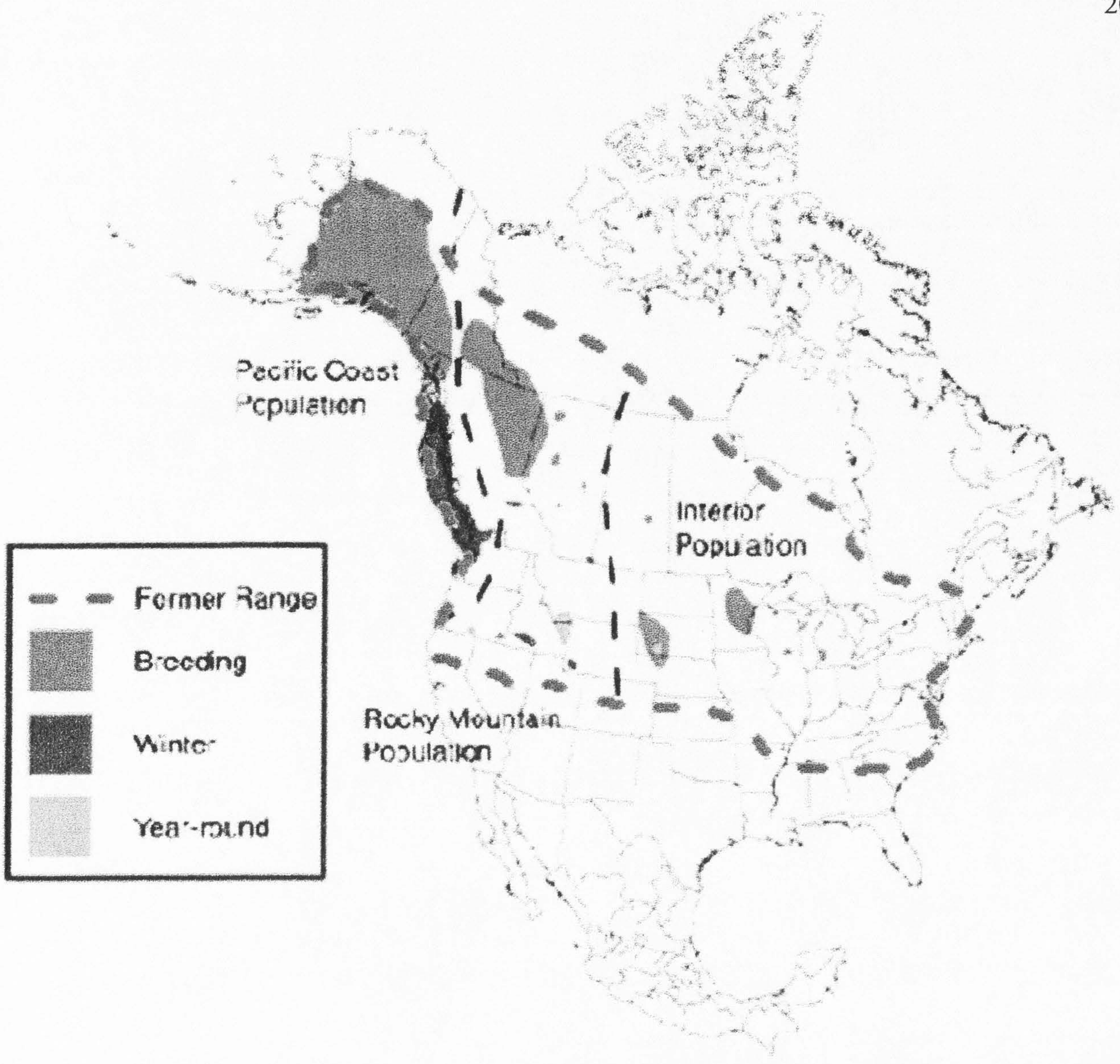

Figure 1.1. Trumpeter swan current and former range (Banko 1960, Mitchell 1994).

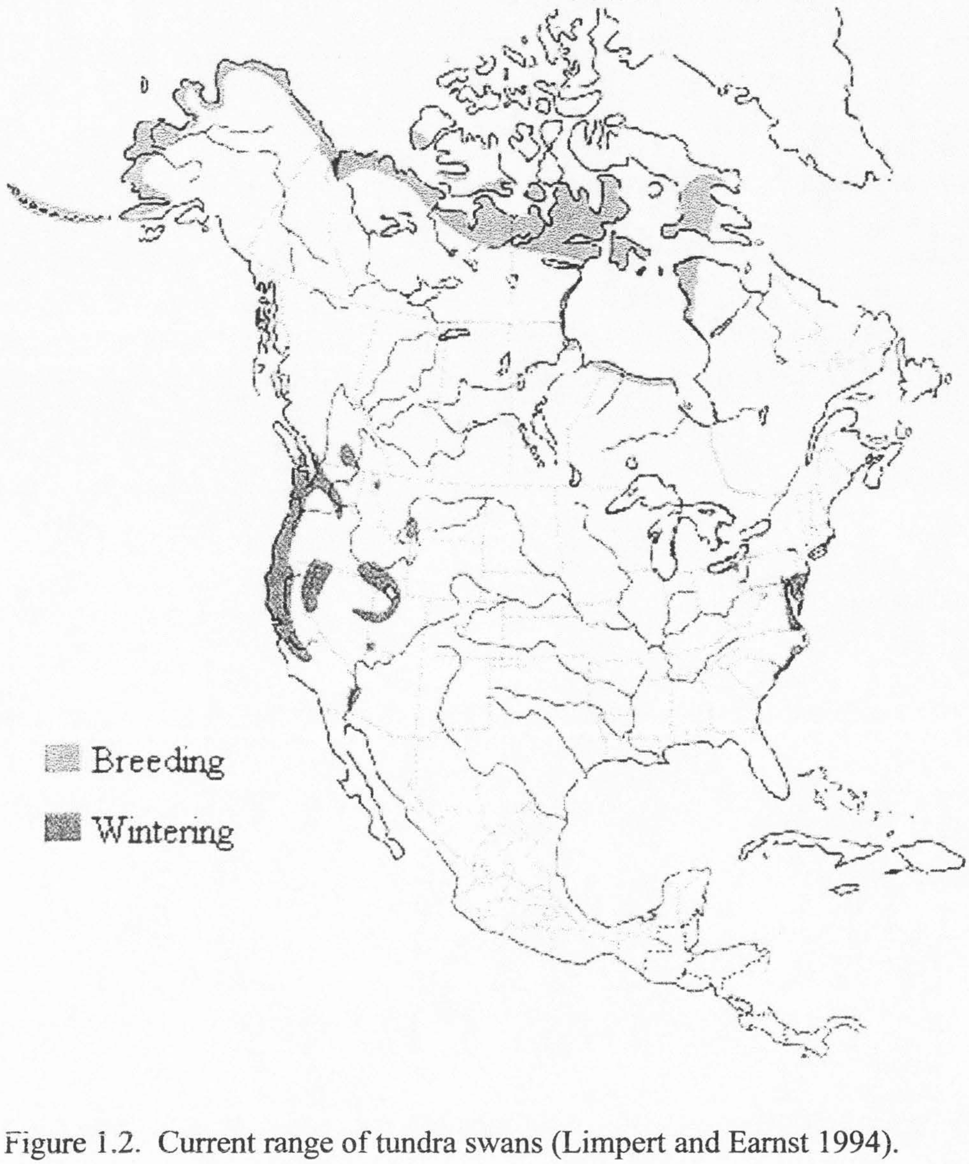

Figure 1.2. Current range of tundra swans (Limpert and Earnst 1994).

CHAPTER 2

SWAN FLIGHT DYNAMICS AND VULNERABILITY

ABSTRACT. -This paper examines the height and velocity of foraging flights for Tundra Swans (*Cygnus columbianus*) and Trumpeter Swans (*Cygnus buccinator*) using the flight dynamics theory developed by Powell and Engelhardt (2000). I applied the flight dynamics theory to 86 Trumpeter and 178 Tundra Swan measurements, predicting flight speed and height for short range foraging flights of both Trumpeter and Tundra swans. Predicted height of flight of Tundra Swans is compared to observations of Tundra Swans made at the United States Fish and Wildlife Service Bear River Migratory Bird Refuge. Average body area of the two species of swans is compared. Trumpeter Swans have on average a 30% larger body area. The flight dynamics theory predicts that Trumpeter Swans fly slower and lower than Tundra Swans; by combining this with the larger body area, Trumpeter Swans are predicted to be 26% more vulnerable than Tundra Swans in a 3.8-km flight. For a 10-km flight Trumpeter Swans are predicted to be 15% more vulnerable than Tundra Swans.

INTRODUCTION

The question of swan vulnerability to hunting is a major conservation issue in Utah and surrounding states (United States Fish and Wildlife Service 2000). The primary reason for this concern is that Trumpeter Swans (*Cygnus buccinator*) are not easily distinguished in-flight from Tundra Swans (*Cygnus columbianus*) (Patten and Heindel 1994). No information is currently available on the relative vulnerability of Trumpeter Swans and Tundra Swans to hunting mortality, especially with regards to species-specific flight trajectories. I used the predicted optimal flight trajectories (Powell and Engelhardt 2000) to determine flight velocities and altitude flown between resting and foraging areas for Trumpeter and Tundra swans. I further used this flight trajectory information to predict harvest vulnerability.

Trumpeter and Tundra swans have been steadily increasing since swan-skin trading ended in the early 1900s (Banko and Mackay 1964). Swan hunting began in Utah in 1962 and continues today. Other states that currently conduct swan hunts are Nevada, Montana, North Dakota, South Dakota, New Jersey, North Carolina, Virginia, and Alaska (Luszcz and Betsill 1988, Bartonek et al. 1991, Drewien et al. 1999). The Tundra Swan population is estimated to be about 120,000 birds (United States Fish and Wildlife Service 2000), approximately half of which migrate through Utah.

Overall, the numbers of Trumpeter Swans have also been steadily increasing; however, the Rocky Mountain Population (RMP) of Trumpeter Swans is of particular concern because the entire population winters in the tri-state area (Idaho, Wyoming, and Montana). Trumpeter Swans were fed at Red Rocks Lakes National Wildlife Refuge from its establishment in 1935 to 1992 (Subcommittee on the Rocky Mountain Trumpeter Swans 1998). This was done to minimize migration to wintering sites in eastern Idaho where it was feared the swans would be illegally hunted. However, as a result of the feeding operations, the learned behavior of migrating beyond the tri-state area has apparently been lost. In addition, it appears wintering habitats cannot support additional population increases, as this may exacerbate habitat deterioration (Shea and Drewien 1999).

The possibility of creating a migration pathway through the Great Salt Lake Basin in Utah and on to the Central Valley of California by translocating Trumpeter Swans to the Great Salt Lake Basin has been investigated (Engelhardt 1997, Shea and Drewien 1999). The majority of the Pacific population of Tundra Swans currently uses this route, and it may be feasible for Trumpeter Swans to follow this well-established migration route. A major management concern for the introduction of Trumpeter Swans into Utah is the vulnerability to hunting harvest during the swan hunt.

The United States Fish and Wildlife Service's (USFWS) Bear River Migratory Bird Refuge (BRMBR), and the Great Salt Lake Basin in particular, are major stop-over points for Tundra Swans migrating from their Arctic breeding grounds to their wintering grounds in California and Oregon (Limpert and Earnst 1994). Tundra Swans generally begin to arrive in the area in late October and have moved on by late December. While in the area, the Tundra Swans tend to make daily flights from resting to foraging areas. These flights are generally short distances (0-20 km) and appear to be a regular routine for the swans. Because the swans are in mid-migration and storing energy for the remainder of their trip, and because the swans are familiar with the area and know how far they are traveling, I hypothesize that the swans fly in such a way as to minimize energy expenditure.

Pennycuick (1989) relates power, or the rate of energy expenditure, required for flight to velocity, and explains that flight speeds for birds can occur between two extreme speeds that can be calculated: the minimum power speed, at which bird requires the least power stay aloft, and the maximum range speed *(V_{mr})*, the speed at which distance is covered most effectively. Though the maximum range speed requires more power, it is more efficient in that the bird has to do less work per unit distance flown. I used an extension of Pennycuick's theory to describe short foraging flights of swans. Following Powell and Engelhardt (2000), I parameterize and validate the theory for Tundra Swans and extrapolate to Trumpeter Swans using the same trajectories. The extension captures the cost of accelerating to take-off speed, which is not negligible for short-distance flights, as well as the benefit in drag reduction gained by climbing to a (slight) altitude. Predicted heights and measured target area (body area of the swan) are then used to estimate an increase or decrease in vulnerability for Trumpeter and Tundra swans.

Following Pennycuick (1989), the mechanical power requirements for a bird's powered flight can be written mathematically as:

$$P(V) = R\left(P_{met} + \frac{C_{ind}}{\rho V} + \frac{C_{pro}}{\sqrt{\rho}} + C_{par}\,\rho V^3\right),$$

where V is the velocity of the bird in level flight, ρ is the density of air, R accounts for respiratory overhead, P_{met} is the basal metabolic power requirement, and C_* are parameters related to *ind*uced, *pro*file and *par*asite power requirements. The actual energetic cost to the swan is higher by a factor of 4.35 due to inefficiency of converting fat to mechanical energy, and even higher if any portion of the flight requires anaerobic respiration. This description of energy consumption per unit time includes: the effects of metabolic power requirements (both basal metabolism and the effect of increasing aerobic respiration under increasing speeds), the power required for lift (induced power), the power required to overcome drag due to the wings (profile power), and the power required to overcome drag due to the body (parasite power). The induced power coefficient is calculated as:

$$C_{ind} = K_i \left(\frac{m^2 g^2}{2 A_{wd}} \right),$$

the profile power coefficient is calculated as:

$C_{pro} = 2K_pA_bC_{Db} (g^2m^2K_i/3A_bA_{wd}C_{Db})^{3/4}$,

and the parasite power coefficient is calculated as:

$$C_{par} = C_{DB} \sqrt{A_b},$$

where body area (A_b) depends on chest height (C_H) and width (C_W):

$$A_b = \frac{\pi}{4} (C_H C_W),$$

and area of the wing disk (A_{wd}) is calculated as:

$$A_{wd} = \frac{\pi}{4} w_s^2.$$

Assumed flight parameters (Powell and Engelhardt 2000) are explained in Table 2.1.

Each of the parameters P_{met}, C_{ind}, C_{pro}, and C_{par} also depends on physical measurements of the swan; in particular the cross-sectional body area (A_b), wingspan and mass of the bird must be known. Given these measurements, it is possible to calculate the most efficient speed for a particular bird to cover a large distance (V_{mr}). Pennycuick et al. (1996) calculated this speed for individual Whooper Swans (*Cygnus cygnus*) and found a velocity of approximately 25 m/s. Units and mean values for Tundra Swans are given in Table 2.2.

In calculating energy costs for short-distance flights, the power costs of take-off and climbing to altitude must be considered (Powell and Engelhardt 2000). Additional observations to determine the time required for take-off (T_{to}) and take-off efficiency (C_{eff}) were collected. Knowing these two parameters, the energetic cost of short distance flights can be calculated. The total energy required for flight at speed V over a distance L (in meters) is:

$$E_{short}(V) = R\left[C_{eff}\left(\frac{1}{4}C_{par}\rho V^3 T_{to} + \frac{1}{2}mV^2\right) + \frac{L}{V}\left(P_{met} + \frac{C_{ind}}{\rho V} + \frac{C_{pro}}{\sqrt{\rho}} + C_{par}\rho V^3\right)\right] \quad (1)$$

The first term in parentheses accounts for acceleration to flight speed while still on the water; because a portion of this acceleration may require anaerobic respiration, the actual energetic costs to the swan are proportionally higher than the aerobic costs of flight. The optimal velocity for a swan to traverse a known distance, (L) is then given by the speed (V) which minimizes E_{short}. Once the optimal short distance speed is known, peak altitude, H (in meters), on an optimal trajectory can also be determined:

$$H = 100\left(\frac{L^2}{8\rho}\right)\left(\frac{C_{ind} + \frac{1}{2} C_{pro} \sqrt{\rho}\, V - C_{par}\, \rho^2 V^4}{C_{ind} - 3\, C_{par}\, \rho^2 V^4}\right) \qquad (2)$$

Details of the derivation of these formulas appear in Powell and Engelhardt (2000). This predicted altitude, H, will be used to help assess relative vulnerability to hunting. Note that this predicted altitude is the height at the highest point in the bird's flight, so that actual observations would be expected to be at or below this height. The parameter C_{eff} is unknown and must be determined from observations by indirect methods.

Using equation (2) height can be calculated at any given stage in a flight of known distance. From Powell and Engelhardt (2000), z is the height of flight at any distance (x) between take-off and landing, which is:

$$z = \frac{\alpha\gamma V}{2\rho_0}\left[\frac{V}{x}(L - x)\right]$$

With H given above (equation 2), z can therefore be calculated in terms of horizontal distance along the flight path x as:

$$z = \frac{4H}{L^2}\left[\frac{V}{x}(L - x)\right]$$

METHODS

PHYSICAL MEASUREMENTS

To obtain the data necessary to test this model I measured 119 and 59 Tundra Swans were in 2000 and 2001, respectively. All Tundra Swan measurements were taken from check stations at the BRMBR and the Utah Division of Wildlife Resources Harold Crane Waterfowl Management Area (Fig. 2.1). A large majority of the measurements were taken on the day of harvest as hunters brought their birds through check stations. Eleven captive Trumpeter Swans were measured in September of 2000 by Bill Long of the Wyoming Wetland Society. These birds were pinioned; therefore, wingspan was taken by doubling the measurement from the tip of the wing to the middle of the back. Eighty-four Trumpeter Swans were measured in May of 2001; these birds had been collected in northern Washington in the winter of 2000-2001, were frozen until May, and defrosted prior to measuring. Most of these Trumpeter Swans were thought to have died of lead poisoning; for this reason, swans with weights less than 7 kg were eliminated as they were presumed to be highly emaciated due to lead poisoning. This left 62 valid Trumpeter Swan measurements. In the winter of 2001, an additional 13 Trumpeter Swan cygnets from Harriman State Park in Idaho were measured before being translocated to the southern end of the state by the Idaho Department of Fish and Game.

The flight theory given above requires measurement of chest height, chest width, wingspan, weight, and time for take-off (Table 2.2). Weight (kg) was measured using a hanging scale; wingspan was taken with swans' wings outstretched and measured from the tip of the second primary on one side, along the leading edge of the wing, to the tip of the second primary on the other side. Chest height was taken by placing a ruler alongside the bird's chest with another ruler across the top of the bird's chest and reading off the intersection. Chest width was taken by placing a ruler across the chest of the bird and using a second ruler to define the start point on one side allowing the end point to be estimated visually. These measurements were all taken with the intent of measuring the body with the feathers as they naturally lie.

Body area measurements were taken by tracing the birds' bodies onto paper. These outlines were then cut out and photographed digitally next to a standard (8.5x11 inch) piece of paper (see Fig. 2.2); by counting pixels in the cut-out and the test sheet, I was able to calculate the area of the swan profile. This method was compared with ten (tedious) physical estimates of area produced by overlaying the outlines with graph paper; the results of these two methods agreed within 1%.

IN-FLIGHT MEASUREMENTS

For the purposes of determining the coefficient of efficiency (C_{eff}), as well as validating the predictions, in-flight measurements of speed and altitude were needed. These measurements were taken for Tundra Swans flying between Unit 1 of the BRMBR and a private duck hunting club, the Bear River Club Company (Fig. 2.3). Take-off time was also measured at this location. Tundra Swans often fly between these two units moving from foraging sites on the Bear River Club Company to resting sites on Unit 1 of the BRMBR. The habit of the swans seems to be to fly to the Bear River Club Company in the morning, shortly after first light, for foraging, and then back to Unit 1 in the evening, using Unit 1 as a night roosting site. Both of these areas are closed to swan hunting. Unit 1 is a rest area (no hunting or trespassing allowed), and while the Bear River Club Company conducts waterfowl hunts, it has very light use. I was only aware of human disturbance to the birds on one occasion. All observations were collected on days without wind or cloud cover.

I initially attempted to use a radar gun to find velocity of birds in flight; however, the birds were infrequently in range and this method quickly proved impractical. I used a laser range finder (Laser Technologies™, Impulse, accuracy ± 15 cm at 150 m) which gives both sight distance to the target and elevation of the target. The height of the laser range finder from the water (i.e., how high above the water level the observer was holding the rangefinder) was then added to the elevation measurement. Speed of flight was determined by measuring the distance of the bird from the observers with the laser range finder and then timing the birds as they flew a known distance between two posts. Using the actual distance, distance to the posts, and the apparent time it took for the swan to travel between the two posts, I was able to calculate the velocity of the swan in flight by similar triangles (Fig. 2.3). In taking this measurement, it is essential that the swans be flying perpendicular to the observer, as deviations would cause an underestimation of actual velocity of the swans in flight. Swans flying at an obvious angle were therefore not measured; however, the actual angles of birds measured could not be easily documented and probably introduced error. Ideally, birds would have been targeted with the laser range finder exactly between the posts. In reality, the laser range finder needed to be panned to follow the birds over a period of a few seconds before a reading was attained. This introduced a second source of error in the in-flight measurements.

CALCULATION OF COEFFICIENTS

Using the average measurements of Tundra Swans harvested at the BRMBR along with observed height and velocity measurements, I estimated C_{eff}. If it is assumed that the observed velocity is the optimal velocity for that swan in the middle of its flight path, I can take the derivative of the equation for $E_{short}(V)$, set it equal to zero and solve for L. That is, I assume that the bird is flying an optimal trajectory and determine L so that the velocity observed is optimal. This gives us a solution for L and leaves the height, H, dependant on the unknown variable C_{eff}:

$$H = -\frac{\left(0.00001\,\mathrm{Ceff}^2\,(1.1\,m + 0.024\,V)^2\,V^8\left(15.73\,m^2 + 1.73\,(m^2)^{3/4}\,V - 0.0044\,V^4\right)\right)}{\left((15.73\,m^2 - 0.013\,V^4)\,(-32.64\,m^2 - 0.958\,m\,V - 3.59\,(m^2)^{3/4}\,V + 0.0091\,V^4)^2\right)}$$

If mass is assumed to be known (e.g., m = 7.18 kg, the average mass of harvested swans), then C_{eff} can be determined from in-flight observations via linear regression. If mass is allowed to vary also, then determining C_{eff} and mass becomes a nonlinear regression problem. Because the model predicts an average bird will fly 16 to 17 m/s for distances greater than 1 km, observations that recorded a velocity below 16.5 m/s were not used to estimate C_{eff}. However, it is possible that observations below 17 were taken from birds flying at an angle, and therefore calculated to be flying slower than they actually were. It is also possible that I had not measured the birds in mid-flight, resulting in altitudes lower than peak *H*. Nonlinear regression was accomplished via Levenberg-Marquadt procedure (Kelley 1999) implemented in *Mathematica*™ (version 4.1, 2000, Wolfram Technologies, Champaign, Illinois). I also eliminated two observations of velocity close to 26 m/s as these two outliers had a strong effect on the model. R-squared for the nonlinear model (mass not assumed) was 0.59, for the linear model (mass assumed) it was 0.68. The nonlinear model also predicted a mass of 7.3 kg, while my actual average mass was 7.4 kg. The nonlinear model gave a C_{eff} of 2.98 and the linear model 2.91. The C_{eff} used in calculation of height and velocity was 2.94, the average of the two estimations. The fitted curves are plotted against the observations in Figure 2.5.

To predict height, I needed to determine the length of the flight. Since this could not be directly measured by observation, I used the equation for height and average measurements for Tundra Swan bodies as well as average in-flight observations to predict a flight length of 3.8 km. As a cross-check on this approach, I compared predicted distance of travel, *L*, with map-based estimates of flight distance; the predicted height seemed reasonable.

STATISTICS

In comparing predicted heights and velocities between Trumpeter and Tundra swans, and comparing predictions to observations I used a t-test ($\alpha = 0.05$).

RESULTS AND DISCUSSION

In total, I measured 86 Trumpeter Swans and 178 Tundra Swans. These measurements were used to predict velocity and height of flight for individual birds using the formula described above for $E_{short}(V)$ (equation 1) and H (equation 2) processed through *Mathematica*™.

VELOCITY AND HEIGHT ANALYSIS

Mean predicted velocity for swans flying 3.8 km was 21.32 m/s for Trumpeter Swans and 21.85 m/s for Tundra Swans ($t = -3.80$, $df = 263$, $P \leq 0.001$, Fig. 2.6). Figure 2.7 shows the clear separation between height of flight for Trumpeter and Tundra swans of the same weight. This difference is due to the larger average wingspan and chest measurements for Trumpeter Swans than Tundra Swans (see Table 2.2), which gives a larger pay-off for climbing to higher altitude via drag reduction. Mean predicted height for Tundra and Trumpeter swans was 53.71m and 50.47m respectively ($t = -4.26$, $df = 263$, $P \leq 0.0001$).

In Figure 2.8, predicted Tundra Swan velocity and height is compared to the observed velocity and height. Recalling that these are the observations I did not use in calculating C_{eff} because their velocities were too low, I would thus expect observed velocities to be lower than predicted. From plotting predicted and observed heights and velocities on the same graph predicted heights are consistently higher than observed.

The 178 predicted heights and velocities were compared with the 128 remaining observed heights revealing a difference in both the heights ($t = -10.16$, $df = 302$, $P \leq 0.0001$) and the velocities ($t = -22.58$, $df = 290$, $P \leq 0.0001$). There are several possible explanations for this difference. It is possible that by selecting birds with a faster velocity to predict C_{eff} and length of flight I am biasing my estimate toward birds flying a greater distance and then comparing it to birds that flew a shorter distance. The length of flight used in my predictions may not be accurate; it seems likely that not all swans observed were flying 3.8 km. Perhaps the reason I was observing lower flight speeds and heights on some birds is because I was measuring the swans as they had already started to descend in preparation for landing. If the latter situation is the case, I can then estimate how high they should be flying in the path of their descent. The birds closest to my observation point were never close enough to measure with the laser range finder (maximum range 300 m); however, they were close enough that I could make out individual birds, and therefore I believe they were between 500 and 1000 m away. If it is assumed that the swans were not landing any closer than 500 m away, a lower bound of height of flight can be created (Fig. 2.8). This lower bound, calculated using equation 1, with a length of 500 m instead of 3.8 km, contains all but two of the height observations made in the field.

Another possible explanation for the predicted velocities being faster than observed is that I collected observations of swans flying at an angle. It is often difficult in the field to determine if the swan is flying exactly perpendicular to the observer or not. I assume any angle greater than 45° would have been noticed by observers in the field; in fact, it seems likely that any angle over 30° would have been noticed, and the measurements would not have been taken on those birds. If it is assumed that any angle greater than 30° would have been noticed, and therefore not recorded by the observer, I can calculate a lower bound of flight velocity (Fig. 2.8). If I apply a 30° angle to my flight predictions, then the actual velocity of flight would be reduced by 15%. This brings my predicted flight velocity closer to the mean of the observations. Applying a 45° angle to my flight predictions would reduce the actual speed of flight by 30%. This still does not encompass all of my data points, suggesting I need a more accurate method of estimating velocity, either in the field or in my model, or both.

Vulnerability Analysis

For the purposes of predicting vulnerability of Trumpeter and Tundra swans, I needed to determine a range in which swans are vulnerable. Olsen and Afton (2000) stated that a snow goose (*Chen caerulescens*) would be in range if less than or equal to 50 m away from the shooter. Davenport et al. (1973) estimate an average kill distance (by field observation of hunters) of 52 m from the shooter, an average crippling distance of 64 m from the shooter, and an average distance of 75 m at which the shooter will not damage the target bird. I compared the proportion of flight trajectory spent in range by both Tundra and Trumpeter swans by assuming that any swan flying at a height of 50 m or less is in harvest range, any swan flying lower than 64 m is at risk of being crippled, and any swan flying above 75 m will not be wounded even if it is shot at. For this analysis, the peak altitude of flight was calculated using average measurements of Tundra Swans and Trumpeter Swans.

For flights of 3.8 km, both Trumpeter and Tundra swans are barely out of kill range for any period in their flight, and would always be within crippling range (Fig. 2.9). The average Tundra swan would be out of kill range for 1000 m of flight, for distances between 1400 m from take-off and 2400 m from take-off, which is 26% of the birds' flight path. The average Trumpeter swan would be out of kill range for 380 m of flight, between 1710 m from take-off and 2090 m from take-off, which is 10% of the birds' flight path. The Tundra and the Trumpeter modeled in this situation barely exit the kill range, reaching a peak height of 53.72 and 50.51 m, respectively.

Spedding and Pennycuick (2001) pointed out that providing uncertainty estimates for predicted height and velocity of birds in flight is critical but often neglected. If uncertainty estimates are included in this plot, then the trend toward Trumpeter Swans flying slower and lower is still present, but the uncertainty estimates overlap the means of each species (Fig. 2.9). Uncertainty estimates for height and velocity were calculated by adding or subtracting one standard deviation to the mean physical measurements of the swans (chest height, chest width, mass and wingspan) and then recalculating the predicted height and velocity (see Table 2.2). Though chest height, chest width, and wingspan are inversely related to mass in my height calculation, these measurements are all correlated with one another. Therefore, to calculate the uncertainty estimates, I uniformly either subtracted or added one standard deviation to my measurements. Uncertainty estimates for a 3.8-km flight are shown in

Figure 2.9. The low uncertainty estimate for Trumpeters overlaps the mean predicted height for Tundra Swans, and the high uncertainty estimate for Tundra Swans overlaps with the mean predicted for Trumpeter Swans.

If a 10-km flight is considered (a likely distance if the swans were flying out to other foraging sites from the BRMBR or the Bear River Club Company), then there would potentially be a larger difference in the amount of time the swans spent in range (Fig. 2.10). The average Tundra Swan would be out of kill range for 8100 m or 81% of a 10,000-m flight, and out of cripple range for 7500 m of flight. The average Trumpeter Swan would be out of kill range for 7430 m or 74% of a 10-km flight, and out of wound range for 6560 m of flight.

If I calculate the uncertainty estimates for this 10-km flight, there is a more pronounced trend towards a lower height of flight by Trumpeter Swans than that seen for the shorter flight. Though there is overlap between the high uncertainty estimate for the Tundra Swan and the low uncertainty estimate for the Trumpeter Swan the means are not encompassed (Fig. 2.10).

Another consideration for vulnerability is the direct effect of physical target area on the likelihood of being shot or wounded. Comparing body area of 55 Trumpeter to 17 Tundra Swans, the Trumpeter Swan is on average 30% larger than the Tundra Swan. The average body area of a Tundra Swan was 0.54 m^2 (± 0.05), while the average body for a Trumpeter Swan was 0.71 m^2 (± 0.06). Haber and Levin (2001) suggest that for objects at a large distance from the observer, people tend to estimate distance using previous knowledge of the size of the object. The worst-case assumption for harvesting would be a swan hunter that is unaware of the possibility of Trumpeter Swans being in the area as well as the size differences between the two species, thereby mistaking the larger Trumpeter Swan in wounding range for a smaller Tundra in kill range (Table 2.2). If that assumption is correct, a 30% larger swan would appear to be 30% closer to a person on the ground, then Trumpeter Swans would appear to be flying at a height of 50 m when they are actually flying at 65 m. This would have the effect of making the Trumpeter appear to be in kill range when in actuality it is only in cripple range.

If hunters shoot at swans that appear to be in kill range and would not generally shoot at swans that appeared to be in cripple range, then, due to the differing size of the bird, the Trumpeter Swan may be more likely to be shot at throughout their flight. Whereas Tundra Swans could be shot at through 74% of a 3.8-km flight and 19% of a 10-km flight, Trumpeter Swans could be shot at through 100% of a 3.8-km flight and 34% of a 10-km flight. Therefore Trumpeter Swans could be up to 26% more vulnerable on a 3.8-km foraging flight, and up to 15% more vulnerable on a 10-km flight.

This estimated vulnerability assumes that hunters are evenly distributed along the flight path of the swans, and that swans 30% larger also appear to be 30% larger. An underlying assumption is that swans shot at 30% more are killed 30% more.

Additionally this vulnerability comparison assumes that Trumpeter and Tundra swans occurring in the area are equally familiar with the area, and follow optimal flight theory for short distance flights. Trumpeter Swans new to the area may not meet this assumption. Swans new to the area may fly lower while searching for appropriate foraging areas. In addition, swans that have been hunted before are likely to behave differently from those who have not been previously exposed to hunting. Tundra Swans at BRMBR tend to avoid areas open to hunting (personal observation). Trumpeter Swans that have not been hunted before and are unfamiliar with the area could be more vulnerable to hunting mortality due to behavioral differences (Engelhardt 1997).

Results of swan hunter surveys in Utah (see Chapter 3) suggest that tundra swan hunters generally underestimate the distance to the swan, but are able to determine if the swan is in range or not. If swan hunters are poor distance estimators, this may actually result in a decrease in the vulnerability between species. If both trumpeter and tundra swans are shot at throughout the portion of their flight spent in kill or wound range, then tundra and trumpeter swans would be equally vulnerable through a 3.8-km flight and trumpeter swans would be 8% more vulnerable through a 10-km flight.

The flight dynamics model is highly sensitive to changes in body measurements. I conducted these same predictions using a weight of 9.8 kg (Langerquist et al. 1994) for all Trumpeter Swans suspected of lead poisoning, with all other measurements were left unchanged. This method predicted height higher than that for Tundra Swans (57.87 m for a 3.8-km flight and 120.48 for a 10-km flight) as well as a faster rate of flight for Trumpeter Swans than Tundra Swans (21.97m/s for a

3.8-km flight and 23.98 for a 10-km flight). If the assumptions stated above are correct, these Trumpeter Swans could be shot at for 100% of a 3.8-km flight and 28% of a 10-km flight.

CONCLUSIONS

This theory predicts that Trumpeter Swans could be up to 26% more vulnerable to hunting mortality on a 3.8-km flight and 15% more vulnerable to hunting mortality on a 10-km flight than Tundra Swans in the same flight path. This assumes that the entire flight path is open to hunting and that swan hunters are randomly dispersed along the flight path of the swans. However this is not usually the case. Swan hunting is only allowed in specific areas around the Great Salt Lake, and even those management areas open to hunting contain rest areas within them that are closed to hunting. Generally, during the hunting season, swans will spend shooting hours in areas closed to hunting, suggesting that as they move from resting to foraging sites the initial portion of their flights and the end of their flights are in areas not open to swan hunting. This behavior may magnify the vulnerability of Trumpeter Swans because they spend more of their flight time apparently in range. In the worst-case scenario, Tundra Swans would be out of range upon entering areas open to swan hunting, whereas Trumpeter Swans would still be in range, this could cause Trumpeter Swans to have an even greater relative vulnerability.

Trumpeter Swans are predicted to fly slower that Tundra Swans as well; however, while significant, the mean predicted velocities were not largely different from one another. Using the predicted values in Table 2.2, Trumpeter Swans would be in flight for 5 seconds longer than Tundra Swans on a 3.8-km flight, and 11 seconds longer on a 10-km flight.

Pennycuick et al. (1999) reported that while Whooper Swans may follow predicted flight speeds during migration, under very special conditions (in this case threat of death from an incoming storm), these conditions rarely occur. Tundra and Trumpeter Swans in the Great Salt Lake area may also follow predicted flight paths under ideal conditions. I attempted to collect my field measurements for verification under ideal conditions, that is, windless, cloudless days. I lacked some important information; specifically, the exact distance traveled by each Tundra Swan whose height and velocity I measured. Ideally, swans would be fitted with a satellite transmitter to record locations every two hours. This method would likely provide an accurate estimate of actual distances flown between resting and foraging areas. Because these birds would have been captured to fit them with the collars, body measurements of the individual birds would be known. If these collars also estimated elevation, then I would only be left with velocity to calculate. This method would be extremely helpful (though extremely expensive) for the validation of these flight models.

MANAGEMENT IMPLICATIONS

Currently Trumpeter Swans are a rare sighting in Utah. However, if Trumpeter Swans are reintroduced into the area, or begin to migrate into the area of their own accord, the species-specific flight trajectories and differing sizes of the swans, coupled with differing behaviors and habits of the two species could have a large impact on relative vulnerability. If an increased population of Trumpeter Swans in the state of Utah is to be expected, then hunter education should be put in place to alert swan hunters of the differences between the two species so as to help reduce the risk of accidental harvest of Trumpeter Swans during the Tundra Swan season. Differences between swan calls and morphology should be emphasized.

In addition, managers should be aware of the species-specific flight trajectories that may cause increased vulnerability for Trumpeter Swans so that appropriate action can be taken should Trumpeter Swans be found in an area. I would suggest that upon locating Trumpeter Swans in the area managers post signs at parking lots and other points of entry for hunters of the area, making them aware that Trumpeter Swans have been spotted in the area and reminding them of the differences between the two species. However, this management recommendation may not be appropriate with current regulations. As stated earlier, it is currently legal to harvest a Trumpeter Swan during the Tundra Swan season; this management recommendation could backfire if swan hunters see this as an opportunity to harvest a Trumpeter Swan.

LITERATURE CITED

Banko, W. E., and R. H. Mackay. 1964. Our native swans. Pages 155-164 *in* Waterfowl Tomorrow (J. P. Linduska, Ed.). United States Fish and Wildlife Service, Washington, D.C.

Bartonek, J. C., J. R. Serie, and K. A. Converse. 1991. Mortality in Tundra Swans. Pages 536-358 *in* Proceedings of the 3rd International Waterfowl and Wetlands Research Bureau International Swan Symposium (J. Sears and P. J. Bacon, Eds.). Wildfowl Supplement Number 1. Slimbridge, England.

Davenport, D. A., G. A. Sherwood, and H. W. Murdy. 1973. A method to determine waterfowl shooting distances. Wildlife Society Bulletin 1:101-105.

Drewien, R. C., J. T. Herbert, T. W. Aldrich, and S. H. Bouffard. 1999. Detecting Trumpeter Swans harvested in Tundra Swan hunts. Wildlife Society Bulletin 27:95-102.

Engelhardt, K. A. M. 1997. Evaluation of translocation criteria for Trumpeter Swans reintroduced to northern Utah: Habitat quality and interactions with Tundra Swans. M.S. thesis, Utah State University, Logan.

Haber, R. N., and C. A. Levin. 2001. The independence of size perception and distance perception. Perception and Psychophysics 63:1140-1152.

Kelley, C. T. 1999. Iterative Methods for Optimization. Society for Industrial and Applied Mathematics, Philadelphia.

Langerquist, J. E., M. Davison, and W. J. Foreyt. 1994. Lead poisoning and other causes of mortality in Trumpeter (*Cygnus buccinator*) and Tundra (*C. columbianus*) Swans in western Washington. Journal of Wildlife Diseases 30:60-64.

Limpert, R. J., and S. L. Earnst. 1994. Tundra Swan (*Cygnus columbianus*). *In* The Birds of North America, no. 89 (A. Poole and F. Gill, Eds.). Academy of

Natural Sciences, Philadelphia, and American Ornithologists' Union, Washington, D.C.

Luszcz, D., and C. Betsill. 1988. Evaluation of a Tundra Swan season in North Carolina. Proceedings of the Annual Conference of the Southeast Association of Fish and Wildlife Agencies 42:388-395.

Olsen, R. E., and A. D. Afton. 2000. Vulnerability of Lesser Snow Geese to hunting with electronic calling devices. Journal of Wildlife Management 64:983-993.

Patten, M. A., and M. T. Heindel. 1994. Identifying Trumpeter and Tundra Swans. Birding 26:306-318.

Pennycuick, C. J. 1989. Bird flight performance: A practical calculation manual. Oxford University Press, Oxford, England.

Pennycuick, C. J., T. A. M. Bradbury, O. Einarsson, and M. Owen. 1999. Response to weather and light conditions of migrating Whooper Swans *Cygnus cygnus* and flying height profiles, observed with the Argos satellite system. Ibis 141:434-443.

Pennycuick, C. J., O. Einarsson, T. A. M. Bradbury, and M. Owen. 1996. Migrating Whooper Swans *Cygnus cygnus*: Satellite tracks and flight performance calculations. Journal of Avian Biology 27:118-134.

Powell, J. A., and K. A. M. Engelhardt. 2000. Optimal trajectories for the short-distance foraging flights of swans. Journal of Theoretical Biology 204:415-430.

Shea, R. E., and R. C. Drewien. 1999. Evaluation of efforts to redistribute the Rocky Mountain population of Trumpeter Swans 1986-97. Department of Biological Sciences, Idaho State University, Pocatello.

Spedding, G. R., and C. J. Pennycuick. 2001. Uncertainty calculations for theoretical flight power curves. Journal of Theoretical Biology 208:127-139.

Subcommittee on the Rocky Mountain Trumpeter Swans. 1998. Pacific Flyway Management Plan for the Rocky Mountain Population of Trumpeter Swans. Pacific Flyway Study Committee, Portland.

United States Fish and Wildlife Service. 2000. Proposal to establish operational general swan hunting seasons in the pacific flyway. Environmental Assessment. United States Department of Interior, Washington, D.C.

TABLE 2.1. Parameters used in calculation of predicted swan height and velocity of flight (Powell and Engelhardt 2000).

Parameter	Description	Value
ρ	Density of Air	1.06kg/m^3 at 1500 m
G	Acceleration due to gravity	9.81 m/sec^2
K_i	Coefficient of induced power	~1.1
K_p	Coefficient of profile power	~0.97
R	Respiratory power overhead rate fraction	~1.1
C_{Db}	Coefficient of drag for body	0.25 (swan)

TABLE 2.2. Average measurements taken from Trumpeter and Tundra swans, 2000 - 2001.

Measurements	Trumpeter Swan	Tundra Swan
Mass (m)	8.75 ±1.05 kg	7.18 ±1.06 kg
Wingspan (w_s)	231 ±8.49 cm	201 ±10.65 cm
Chest Height (C_H)	19 ±1.71 cm	16 ±1.43 cm
Chest Width (C_W)	25 ±1.79 cm	23.5 ±2.33 cm
Frontal Area of Body (A_b)	370.15 cm^2 ± 50.09	301.37 cm^2 ± 45.05
Area of Wing Disc (A_{wd})	4.16 m^2 ± 0.34	3.19 m^2 ± 0.34
Take-off Time (T_{to})	-----	7 sec
Flight Length = 3.8 km		
Height[a]	51.23 +2.13 -4.22 m	53.96 +1.72 -2.53 m
Velocity[a]	21.44 +0.0 -0.17 m/sec	21.97 +0.17 -0.05 m/sec
Flight Length = 10 km		
Height[a]	105.99 +3.61-8.15 m	112.47 +2.87 -4.73m
Velocity[a]	23.36 -0.11 -0.14m/sec	23.98 +0.0 -0.14 m/sec

[a] Uncertainty estimates for height and velocity were calculated by adding or subtracting one standard deviation from all physical measurements.

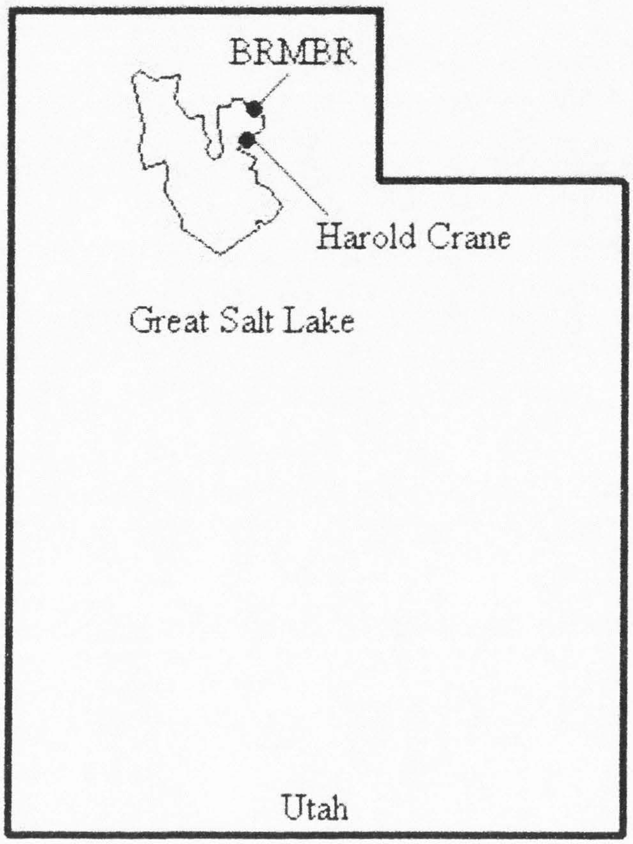

FIG. 2.1. Location of swan hunter check stations (at the Bear River Migratory Bird Refuge (BRMBR), and the Harold Crane Waterfowl Management Area), 2000 - 2001.

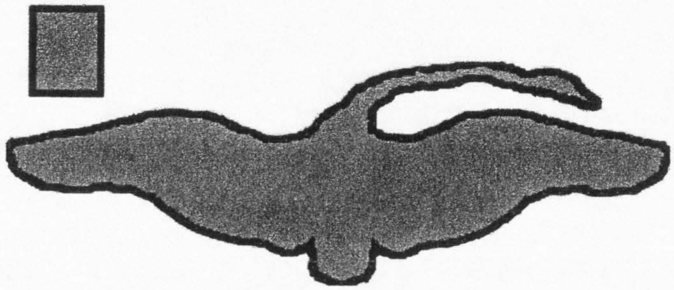

FIG. 2.2. Estimation of swan body area. (To calculate the body area of a swan, a digital photo of a swan tracing was taken with a test sheet of 8½x11 inch paper. The number of pixels contained in the test sheet and swan tracing were counted, thus determining the body target area of the swan.)

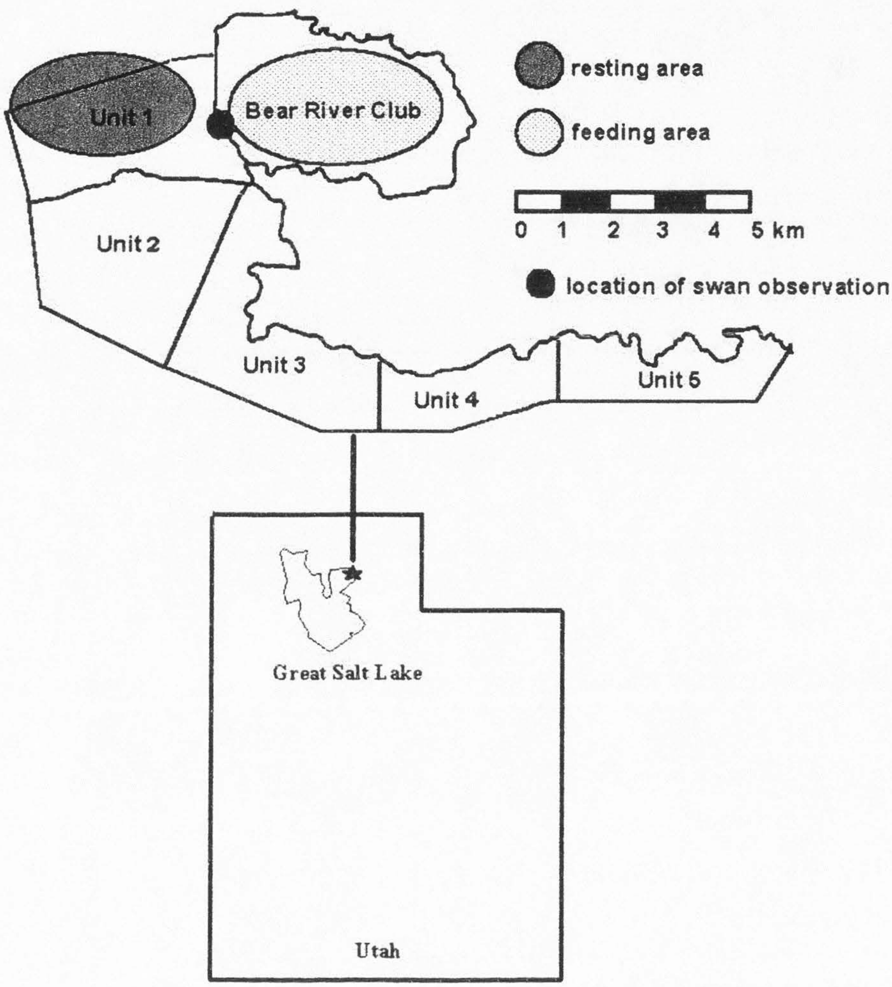

FIG 2.3. Location of in-flight swan observations. (At the United States Fish and Wildlife Service Bear River Migratory Bird Refuge, and the Bear River Club Company, Box Elder County, Utah, 2000-2001.)

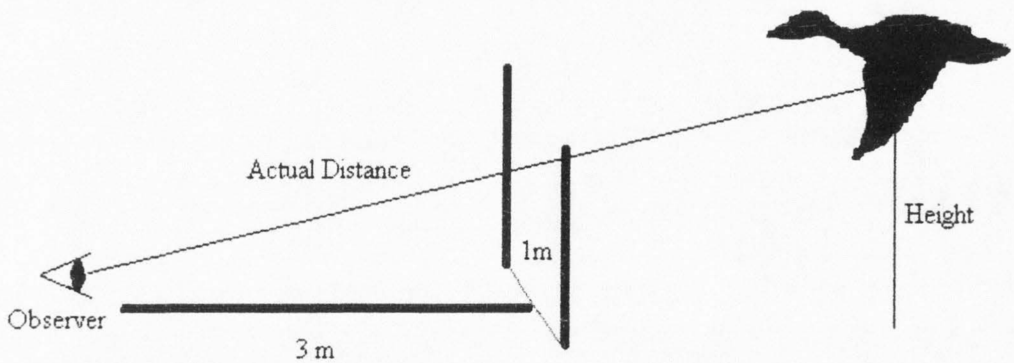

FIG. 2.4. Method for in-flight swan observation. [Actual distance to the bird and the apparent time it took the bird to fly between the two posts placed 1 m apart were used to calculate velocity of flight (V), using similar triangles, V = (actual distance to the swan)(1 m)/(3 m x time).]

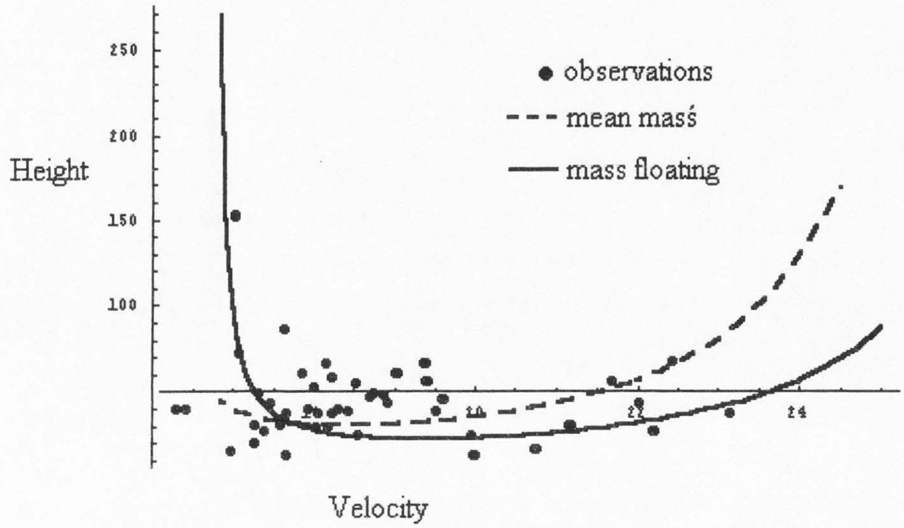

FIG. 2.5. Coefficient of efficiency. (The fitted curve of C_{eff} for linear (mean mass) and non-linear (floating mass) regression is plotted with observation points, with a flight length of 3.8 km. The C_{eff} should be the curve that fits the observation points best.)

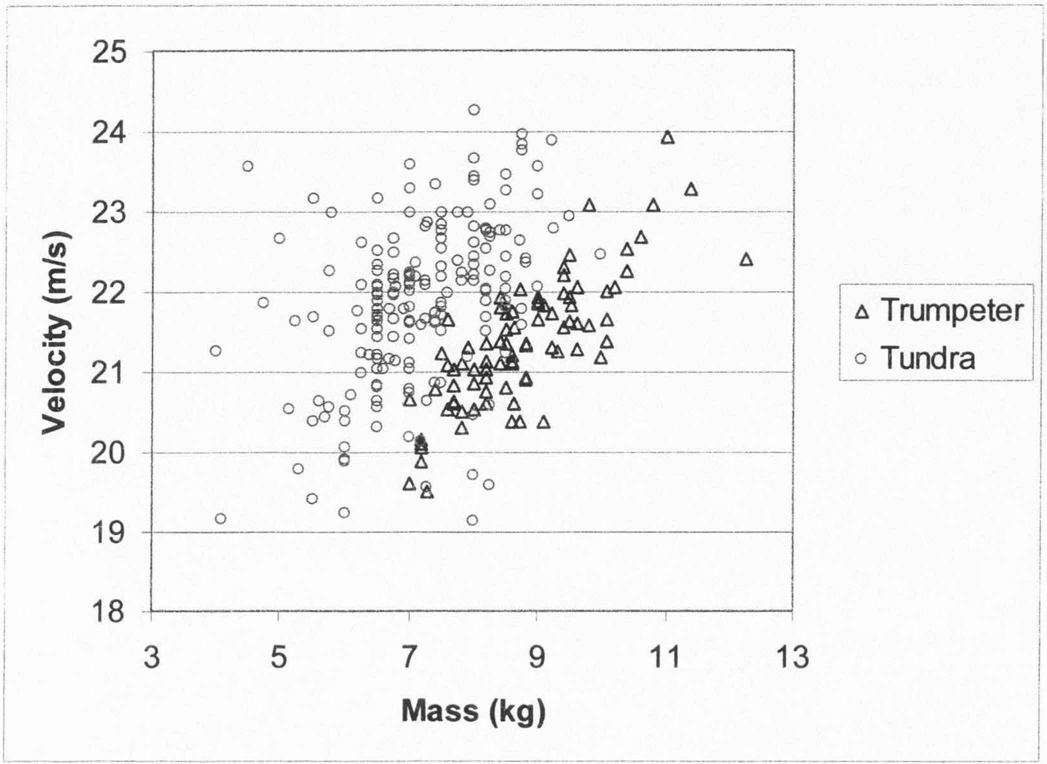

FIG. 2.6. Predicted swan velocity vs. mass for a 3.8-km flight using the optimal flight theory. (The circles represent Tundra Swans and the triangles represent Trumpeter Swans. Note the separation in velocity for Trumpeter and Tundra swans of the same weight.)

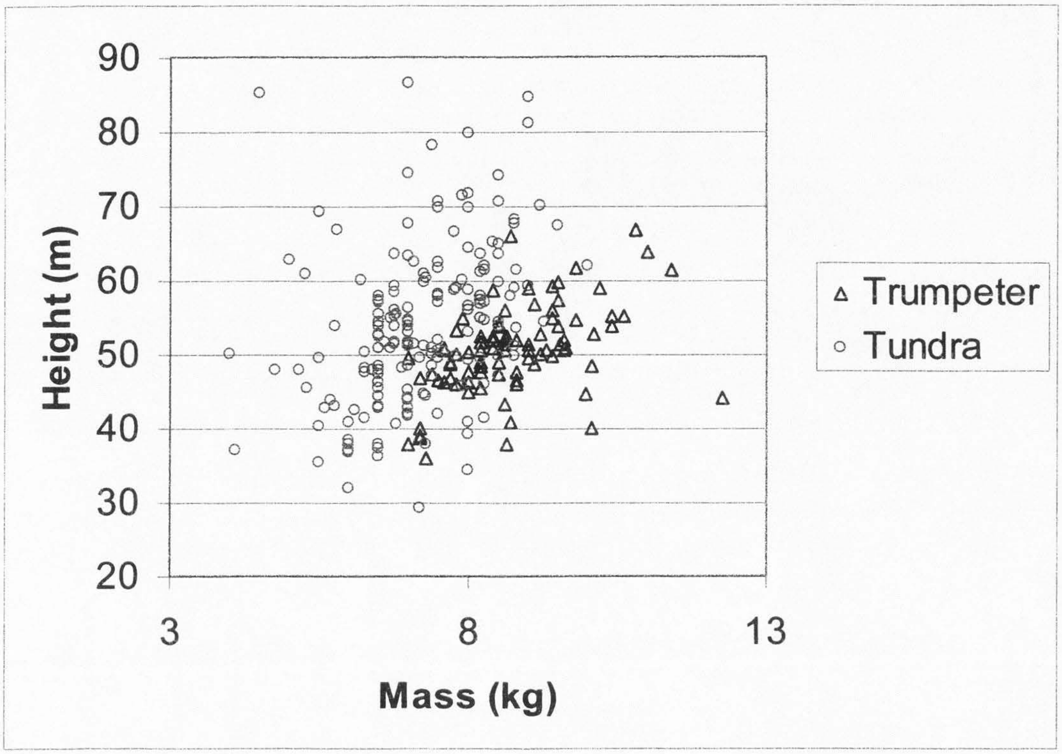

FIG. 2.7. Predicted swan flight height vs. mass for a 10-km flight. (The circles represent Tundra Swans and the triangles represent Trumpeter Swans. Note the separation in height for Trumpeter and Tundra swans of the same weight.)

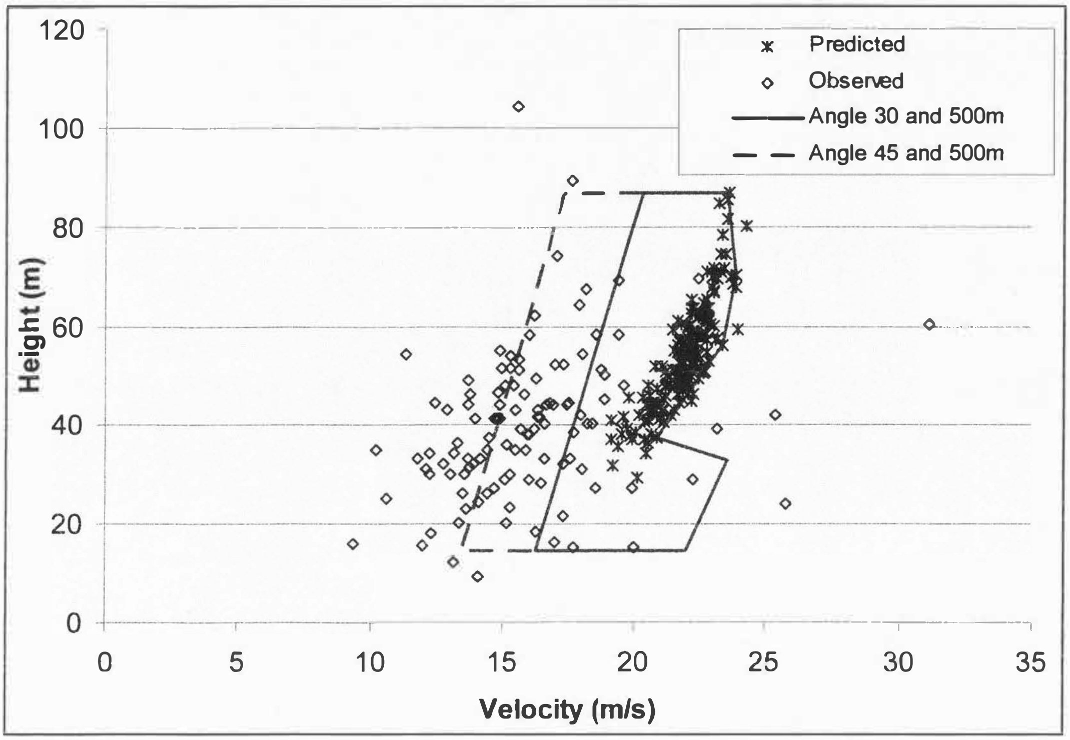

FIG. 2.8. Predicted and observed flight height and velocity for a 3.8-km flight. (The observations tend to be much lower than the predicted. Bounds are shifted to the left where predictions include swans were flying at an angle; 30° for the solid line and 45° for the dashed line. Bounds are shifted down where the swans are assumed to be 500 m away from landing).

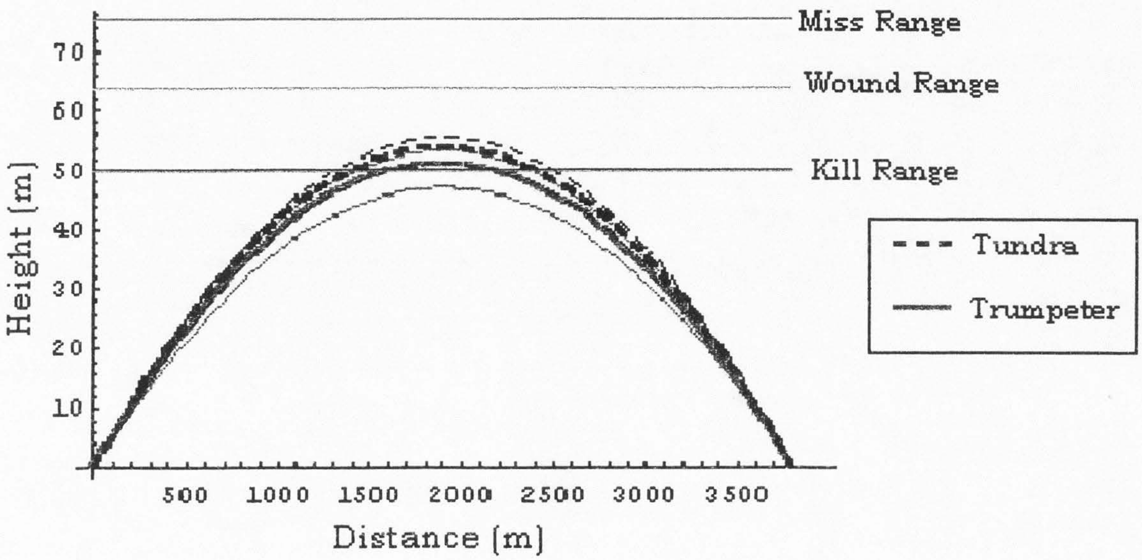

FIG. 2.9. Predicted height of a 3.8-km swan flight, with uncertainty estimates. (Tundra Swans and their uncertainty estimates are represented by the dashed lines, Trumpeter Swans and their standard deviations are represented by solid lines. Heavier lines indicate mean predictions, lighter lines indicate uncertainty estimates. Tundra Swans are predicted to be in kill range through 74% of their flight, Trumpeter Swans are predicted to be in kill range through 90% of their flight and in wound range through 100% of their flight. Note the overlap between the predicted heights of the two species.)

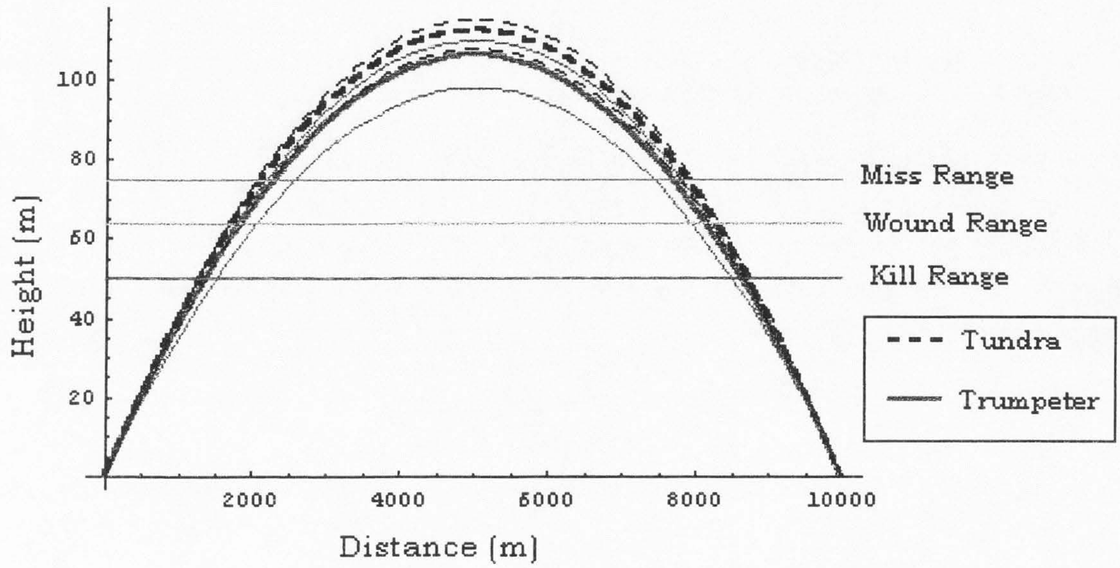

FIG 2.10. Predicted height of a 10-km swan flight, with uncertainty estimates. (Tundra Swans and their uncertainty estimates are represented by the dashed lines, Trumpeter Swans and their standard deviations are represented by solid lines. Heavier lines indicate the mean. Tundra Swans are predicted to be out of kill range for 81% of this flight. Trumpeter Swans are predicted to be out of kill range for 74% of this flight and out of wound range for 66% of this flight. While the predicted heights uncertainty estimates overlap the tendency is to predict lower height for Trumpeter Swans.)

CHAPTER 3

CHARACTERISTICS OF UTAH SWAN HUNTERS: IMPLICATIONS FOR TRUMPETER SWAN CONSERVATION

Abstract Trumpeter swans are occasional visitors to Utah during the swan hunt. Because trumpeter swans are extremely difficult to distinguish from tundra swans, they are subject to hunting pressure during the swan hunting season. The Utah Division of Wildlife Resources is interested in implementing a swan hunter education course to reduce the likelihood of a trumpeter swan being harvested during the swan season; however, little information is currently available on swan hunters for developing this program. This paper presents the results of swan hunter surveys conducted in Utah in the 2000 and 2001 swan seasons at the United State Fish and Wildlife Service Bear River Migratory Bird Refuge (BRMBR) and the Utah Division of Wildlife Resources Harold Crane Waterfowl Management Areas. The results of this study indicated Utah swan hunters would be receptive to a swan hunter education course and are receptive to current swan hunting regulations. This education course should include information on distinguishing between the two species, regulations of the swan hunt, and distance estimation techniques.

Introduction

There are two species of swans that occur in Utah, trumpeter swans (*Cygnus buccinator*) and tundra swans (*Cygnus columbianus*). The trumpeter swan was once widespread throughout North America; however, by the early 1900s, they had been hunted nearly to extinction (Phillips 1911, Mitchell 1994). Trumpeters were likely to be more vulnerable to hunting in comparison to tundra swans because their breeding areas tended to be further south than tundras' and thus were more accessible to early fur traders and settlers. In 1935, the only known population of trumpeters was a small remnant flock of 65 trumpeters in the Yellowstone area. Other flocks were discovered later, including a flock of about 100 trumpeters in the Grand Prairie area of Alberta and another of about 200 trumpeters on the Kenai Peninsula of Alaska. The trumpeter swan population in North America has since increased to 19,000 (United States Fish and Wildlife Service 2000).

Continental tundra swan populations were also declining in the mid to late 1800s (Banko and Mackay 1964). However, their breeding grounds were largely unexplored by hunters and trappers; therefore, population declines in tundra swans were not as severe as trumpeters (Banko and Mackay 1964, Limpert and Earnst 1994). The tundra swan population in North America is estimated to exceed 120,000 birds (United States Fish and Wildlife Service 2000).

Swans are currently hunted in Utah during the fall migration period under guidelines established by United States Fish and Wildlife Service (USFWS). Because of the interest in reestablishing a trumpeter swan migration corridor through Utah, some are concerned that continuation of the swan hunt in Utah could impact efforts to restore regional trumpeter swan populations (United States Fish and Wildlife Service 2000). Trumpeter and tundra swans are difficult to differentiate in the field (Patten and Heindel 1994). Because of this difficulty, trumpeters would be vulnerable to harvest during the swan hunt.

Utah conducted its first swan hunt in 1962. The hunt was established because of increased public interest. Since the beginning of the hunt the Utah Division of Wildlife Resources (UDWR) has closely monitored tundra swan populations and determined that the hunt is not negatively impacting the population. Given the strong public demand to continue the hunt as well as increased public interest in restoring regional trumpeter swan populations, the UDWR and USFWS implemented regulations designed to reduce the vulnerability of trumpeter swans during the swan hunt (Tessmann 2000). These regulations include an early closure of the swan season. Previously the swan season closed at the same time as the duck and goose season; however, trumpeter swan advocates argued that if the season was closed earlier trumpeter swan vulnerability may be reduced because these swans tend migrate later in the season than tundra swans. Areas where the relative abundance of trumpeter swans is high, such as along the green river, and areas that tend to have smaller ponds favored by trumpeter swans, such as state areas north of BRMBR, have been closed to swan hunting (Engelhardt 1997, Pelizza 2000). Currently if 10 trumpeter swans are harvested in a swan season in Utah, the swan season is closed for the year, but as of yet this has not occurred. In addition, all successful swan hunters are required to have their birds checked. Hunters are also required to complete a short survey, indicating success of hunt. Any hunter who fails to complete the survey is ineligible to apply for a swan hunting permit the following year (Utah Division of Wildlife Resources 2001).

Despite these regulations some trumpeter swan conservation proponents continue to seek complete closure of the swan hunt in Utah. In an effort to further address their concerns, the UDWR has proposed implementation of a mandatory swan hunter education course. However, little is known about the characteristics of swan hunters. This information will be needed to develop an effective course.

Role of hunter surveys in wildlife management

Past studies of hunter characteristics have provided wildlife management with useful information. For example, Langenau and Mellon (1980) summarized hunting habits of young hunters in Michigan, including where they hunted, what they hunted, and success rates in an effort to predict where hunter education programs should be focused in the future. Gratson and Whitman (2000) surveyed elk hunter characteristics and hunting experience and compared this to opinions of road closure regulations to determine characteristics of hunters using specific areas. Their study identified where educational efforts should be focused. Dahlgren et al. (1977) studied at the relationship between level of understanding of wildlife principles and other characteristics of the general public in Iowa. Their results suggested that education programs should include contacts with wildlife in a natural setting. In addition, they concluded that there is a growing anti-hunting sentiment; therefore, managers should also focus on improving the quality of hunting and non-hunting aspects of wildlife management.

Nieman et al. (1987) compared hunter observations to bag checks and interviews conducted with hunters to determine hunters' identification skills, species taken by hunters, crippling loss and hunting regulation violation. The authors suggested lowering the bag limits would reduce the hunting violations and crippling losses. They also suggested that species-specific regulations are not likely to be effective due to the nonselective nature of the current hunter harvest, even in areas with species-specific regulations.

The only published study on tundra swan hunters was conducted in North Carolina. Luszcz and Betsill (1988) monitored the tundra swan hunt to assess hunter success, effort and performance. However, their survey did not specifically identify hunter characteristics and motivations. More information on swan hunter characteristics and motivations is needed to assist the UDWR and other states in developing programs that achieve management objectives. This survey was conducted to determine general characteristics of the swan hunters in Utah as well as their attitudes toward current management practices.

Methods

Study area

Surveys were administered to swan hunters who visited check stations after hunting swans in northern Utah. The check stations were established at the USFWS Bear River Migratory Bird Refuge (BRMBR), located in Box Elder County during the swan season in 2000 and 2001 (see Figure 2.1). Additional surveys were administered at check stations operated at the UDWR Harold Crane Waterfowl Management Area (HCWMA), located in Weber County, during the fall of 2000 (see Figure 2.1).

The bulk of the tundra swan migration comes through the BRMBR; therefore, most Utah swan hunters hunt the BRMBR. For this reason, my survey efforts focused on BRMBR swan hunters. Because tundra swans are also hunted at the HCWMA and to a lesser extent at other state waterfowl management areas, I surveyed swan hunters here to determine if they differed from the BRMBR hunters. Hunters of the HCWMA were only surveyed in 2000 because of logistical constraints and the lack of a difference between BRMBR hunters and HCWMA hunters.

The survey was administered to hunters as they stopped at check stations upon exiting hunting areas. In 2000, check stations were manned in the morning and evening on weekends (from Friday evening to Sunday evening). In 2001, check stations were manned daily from the start of shooting hours to two hours after shooting hours ended, throughout the swan season.

Initially, only successful hunters were given surveys as they left the refuge. During the last two weeks of the season, unsuccessful hunters were surveyed as well because I assumed they would be less likely to return to the refuge to hunt swans as the season was closing. At this point, all hunters exiting the refuge were asked to complete swan hunter surveys. This allowed me to compare successful and unsuccessful hunters to determine if there were any factors that might have contributed to increased hunter success.

Study questions

Surveys consisted of 51 questions in 2000 and 53 questions in 2001. Questions added in 2001 included whether the respondent had completed the survey the previous year, hunting methods (pass shooting, decoys or stalk and shoot) and hunting set up (use of boats, blinds and decoys). In 2000, hunters were only asked to identify the method of hunting (i.e., pass shooting, blinds or blinds with decoys). In 2000, hunters were asked to rate their duck identification skills as poor (would have difficulty identifying most common Utah ducks on the wing), fair (could identify some of the common Utah ducks on the wing), good (able to identify most of the common Utah ducks on the wing), very good (able to identify the common Utah ducks on the wing), or excellent (could identify every duck in Utah on the wing). In 2001, I wanted to get more specific information on hunters' waterfowl identification skills. To do so, hunters surveyed were provided with a list of 12 ducks in Utah and asked to indicate which they would be able to identify on the wing.

In addition to questions designed to ascertain hunter demographics, hunters were asked about their swan hunting experience in particular, hunting techniques, harvest success, and circumstances of harvest. Opinions of swan hunting regulation and knowledge of current regulation were assessed by asking hunters whether certain regulations increased or decreased the quality of the hunt. Hunters were also asked to identify the number of trumpeter swans that could be harvested in a season before the season would be closed for the year. Lastly, hunters were asked to estimate shooting distances. I did this by asking hunters to estimate the distance to a life-sized silhouette of a tundra swan that was placed approximately 1 meter off the ground on a post. The silhouette was placed at either 64 or 77 meters from the hunter. In order to avoid the influence of previous hunters' responses, hunters were individually asked to estimate distance to the silhouette. Hunters were asked if they considered the silhouette to be in range and how far away they estimated it to be in yards (estimates were subsequently converted to meters for reporting). Their estimates were compared to the actual distance, the silhouette was considered to be in range if it was less than 50 meters away (Olsen and Afton 2000).

Statistical analysis

I conducted a chi-squared test comparing responses between years and successful vs. unsuccessful hunters to test if year or hunter success had affected survey responses ($\alpha = 0.05$). Those variables that were not affected by year or success of the hunter were then combined across year and success for further analysis.

Results

Number of respondents

Of the 181 swan hunters surveyed in 2000, 102 had harvested a swan (56%). In 2001, 109 surveys were completed by swan hunters, and 80 were successful (73%). In 2000, I surveyed 9% of all Utah hunters who had been issued swan permits. In 2001, I surveyed 5% of all Utah swan permit holders.

General characteristics

Ninety-one percent (n = 254) of the survey respondents were male, most had at least completed high school (93%, n = 275), and were married (70%, n = 278). Thirty-three percent (n = 264) of the respondents belonged to a conservation organization. Most of these (82%, n = 89) were members of Ducks Unlimited. Most swan hunters also hunted ducks and geese (94%, n = 275), big game (88%, n = 275) and upland game (84%, n = 275). Few hunted furbearers (8%, n = 275), cougars (8%, n = 275), or bears (6%, n = 275).

Swan hunters identified most with hunting for the trophy (53%, n = 272), and for the meat (52%, n = 272). They identified least with participation in the swan hunt because of the high chance of success (11%, n = 272), tradition (32%, n = 272), or accessibility (12%, n = 272). Most swan hunters hunted ducks and geese the year before (86%, n = 280), and the year of the survey (86%, n = 279). Mean number of days spent hunting ducks and geese the previous year was 12 (n = 273).

In 2000, hunters were asked to rate their duck identification skills. Swan hunters tended to rate their duck identification skill as good (30%, n = 173), or very good (38%, n = 173), few rated themselves as excellent (14%, n = 173), or fair (18%, n =173). In 2001, hunters surveyed were provided with a list of 12 ducks in Utah and asked to indicate which they would be able to identify on the wing. On average respondents indicated they were able to identify 7 (SD = 3.2, n = 103). Most swan hunters knew at least some of the differences between trumpeter and tundra swans (65%, n = 223). Though answers differed by year, swan hunters were aware of the efforts by some special interest groups to close the swan season in Utah (79%, n = 173; 89%, n = 98; in 2000, 2001, respectively).

In 2001, the UDWR began to investigate the possibility of developing an on-line swan-hunter education course. At their request, I added questions regarding internet access to the hunter survey. Seventy-five percent (n = 44) of respondents indicated they had internet access either at home or at work or both.

Effects of year and hunter success on responses

Hunters surveyed in 2001 had lived in Utah longer ($\chi_3^2 = 11.77$, P = 0.008), were older ($\chi_4^2 = 20.54$, $P \leq 0.001$) and were more likely to be members of a conservation organization ($\chi_1^2 = 4.34$, P = 0.04) than hunters surveyed in 2000. They also had spent more years hunting in Utah ($\chi_4^2 = 14.27$, P = 0.007), and had hunted ducks and geese longer ($\chi_4^2 = 21.75$, $P \leq 0.001$). Hunters surveyed in 2001 generally spent more days duck and goose hunting that year ($\chi_4^2 = 13.53$, P = 0.009), had been hunting swans for a longer period of time ($\chi_3^2 = 13.86$, P = 0.003), approved more of the swan-permittee-only hunting areas ($\chi_1^2 = 10.07$, P = 0.002), were more knowledgeable of special interest group involvement in the swan hunt ($\chi_1^2 = 4.43$, P = 0.04), and knew how many trumpeter swans could be harvested in the season before the closure of the swan hunt ($\chi_1^2 = 0.27$, $P \leq 0.001$) than hunters in 2000. Hunters in 2001 were also less likely to identify a high chance of success ($\chi_1^2 = 4.97$, P = 0.03) or challenge ($\chi_1^2 = 4.15$, P = 0.04) as a reason for participating in the swan hunt than hunters surveyed in 2000.

Successful hunters were more likely ($\chi_1^2 = 10.96$, $P \leq 0.001$) to be members of a conservation organization. The number of years hunting swan was also positively correlated with success ($\chi_1^2 = 4.76$, $P = 0.03$). Successful hunters were more likely to know how many trumpeter swans could be harvested in a season ($\chi_1^2 = 2.67$, $P = 0.04$) and less likely to identify the ease of the hunt as a primary reason for participating ($\chi_1^2 = 7.00$, $P = 0.008$) than unsuccessful swan hunters.

Swan hunters experience

Most swan hunters surveyed had not hunted swan the previous year (60%, n = 267). Of those that had hunted swan the previous year, most had spent 2-5 days hunting (55%, n = 106), 54% (n = 115) had harvested a swan and 90% (n = 62) of those had had their swan measured (Table 3.1). Most hunters estimated they harvested their swans at distances less than 37 meters away (77%, n = 166). Swans were generally flying to the hunter (64%, n = 184), in a small flock (less than 10 birds, 67%, n = 177). Most swan hunters used a 12 gauge shotgun (80%, n = 267), 8.9 cm (3.5 inch) shells (59%, n = 261), and steel shot (83%, n = 268). Hunters generally did not use decoys (75%, n = 269), but most would consider using them in the future (68%, n = 262). Usually, 3 or fewer shots were fired to harvest a swan (63%, n = 138). Ninety-three percent of respondents said they had not wounded any swans. Swan hunters had spent between 2 and 5 days hunting (49%, n = 195), spending more than 2 weekdays (60%, n = 178), and more than 2 weekend days hunting(64%, n = 177), and hunted with 2 or more companions (53%, n = 261).

Distance estimation

Forty-three swan hunters were tested in their abilities to estimate distances were tested, I found 32% of hunters believed a silhouette at 64 meters was in range; average distance estimated for this silhouette was 50 ±15 meters. Twenty-five percent of hunters estimated a silhouette at 77 meters to be in range. The average distance estimated for this silhouette was 60 ±12 meters.

Response to swan hunting regulations

In 2000, swan hunters were asked whether they would stop swan hunting if a hunter education course were required of them. Seventy-six percent of respondents (n = 174) indicated they would continue to swan hunt. In 2001, the same question was asked, adding that it would be a 3-hour internet course. Sixty-three percent (n = 56) indicated they would continue to swan hunt. Swan hunters in 2001 were also asked if raising the cost of a swan tag from $5 to $15 would stop them from hunting swan; 64% (n = 104) indicated it would not.

Special regulations on the swan hunt at the BRMBR had a high approval rating. Most hunters believed the 10 shell limit (64%, n = 255) and the restricted parking (83%, n = 252) increased the quality of the swan hunt. Although responses to the question of whether the swan-permittee-only area on the refuge increased the quality of the hunt differed between years, respondents in both years tended to agree that the regulations increased the quality of the swan hunt (81% and 63% in 2000, and 2001 respectively). The difference in approval of the swan-permittee-only area may have to do with changes in the behavior of the swans and water levels on the refuge. In 2000, the swan-permittee-only area was heavily used by swans and swan hunters. However, at the beginning of the season in 2001, the swan-permittee-only area was dry and even after the water returned the swans did not use it; therefore, neither did the swan hunters.

In 2000, hunters were asked if they would stop hunting if they were required to take a hunter education course. In 2001, this question was modified to ask if they would stop hunting if they were required to take a three hour, on-line hunter education course. I combined these answers to determine if there was any difference between those hunters that would discontinue swan hunting and those that would not. Those who would continue to hunt were more likely to be members of conservation organizations ($\chi_1^2 = 11.91$, $P \leq 0.001$), were more aware of special interest group involvement ($\chi_1^2 = 10.71$, $P \leq 0.001$), were less likely to identify ease as a reason for participating in the swan hunt ($\chi_1^2 = 5.90$, $P = 0.02$), tended to approve of the swan-permittee-only area on the refuge ($\chi_1^2 = 3.69$, $P = 0.05$), and were more likely to harvest a swan ($\chi_1^2 = 7.74$, $P = 0.005$).

Discussion

The results of this survey indicated that most Utah swan hunters are experienced waterfowl hunters who are interested and concerned about preserving the current tundra swan hunt and reducing the risks of harvesting a trumpeter swan. The majority of swan hunters also hunt ducks and geese, and rate themselves as having either good or very good waterfowl identification skills. Most are aware of at least some of the differences between trumpeter and tundra swans and would be willing to participate in a swan hunter education course.

In 2000, I surveyed 9% of all swan hunters in Utah; in 2001, I surveyed 5%. Though this represents a relatively small sample of all the Utah swan hunters, the percentage of hunters sampled is consistent with accepted statistical guidelines (Dillman 1978). The surveys focused on hunters at the BRMBR; I believe this survey is representative of swan hunters in Utah because the majority of the swan hunting occurs on this refuge. The BRMBR has the highest concentration of swans of any area currently open to swan hunting in Utah, and therefore the highest concentration of swan hunters. In addition, no differences were observed in characteristics between swan hunters at the HCWMA and the BRMBR

I was initially concerned that the change in sampling technique (i.e., surveying both on weekdays and weekends) affected the responses. Had this happened, I would have expected to see a difference in responses to questions regarding number of week days, and number of weekend days spent hunting. However, there were no differences in responses to these questions between years.

The obvious bias toward male hunters is not surprising given that less than 1% of females in the state hunt (United States Department of Interior and United States Department of Commerce 1998). Swan hunters surveyed in both years rated themselves as being very good or good at identifying ducks on the wing. While the questions were phrased differently between years, the results were essentially the same; most were able to identify most or all of the common ducks in Utah on the wing.

Swan hunters who indicated they would continue to hunt swans if a swan hunter education course were required were generally more interested in issues surrounding the swan hunt, and had a greater level of knowledge of the resource. According to hunter responses wounding rate for the swan hunt was 0.11 swans wounded per swan hunter. Nieman et al. (1987) compared crippling rates observed in the field to crippling rates reported by hunters in Saskatchewan and Manitoba. Hunters in the study reported crippling 6-18%, though observed losses were usually 20-45%. My documented crippling rate falls within that reported in Niemans' study. However, I was unable to conduct field studies to verify hunter reports. Thus, it is possible that actual crippling rates could have been higher. Because hunter surveys were entirely anonymous, not conducted by law enforcement personnel, and hunters completed surveys themselves, so their motivation to lie about crippling rates should have been minimal (Dillman 1978); however, the state estimates the wounding rate of swans to be 0.17 (T. Aldrich, Utah Division of Wildlife Resources, personal communication).

Management Implications

The results of this survey suggest that Utah swan hunters would be receptive to a hunter education course. They expressed an interest in doing what was needed to reduce the risk of harvesting a trumpeter swan during the general swan season. This concern was further substantiated by their support of current regulations to include the 10 shell limit. My results suggest that to maximize the effectiveness of a swan hunter education course, it should incorporate several key components. These include swan identification techniques, regulations, and distance estimation.

Methods to enhance distance estimation might include a photograph of the bead of a shotgun pointed at a swan silhouette at variable distances. Although this depiction could reduce crippling losses for tundra swans, it may not address the issue of differences in the relative size of the two species of swan. This module of the hunter education course might be improved by pointing out additional key characteristics of the differences between swan species that hunters should be looking for at while they are estimating distance to the swan.

It would be important to include differences in calls of the two birds, as these are rather distinctive and are the best tools for identification of the species, especially from long distances (Patten and Heindel 1994). The education course also should include information of species-specific flight trajectories (see Chapter 2), to make swan hunters aware of potential differences in flight patterns of the two species.

The course also should emphasize regulations. Although most hunters that were aware of the regulations allowing the take of 10 trumpeter swans during season, some were not. This misperception could be counterproductive to the UDWR in goals of ensuring all swans are checked. The education course could further reinforce the need for all hunters to have their swans checked by dispelling the fear of legal action against those that harvest a trumpeter swan. A major objective of the program is to motivate hunters to learn the differences between species so that the general swan hunt can be continued.

My survey results suggest that most hunters who currently participate in the Utah general swan hunt are experienced waterfowl hunters. Most of these hunters are aware of the role of regulations and educational programs in harvest management. They expressed both support for current general swan hunt regulations at BRMBR, and an interest in doing what the UDWR felt was necessary to reduce the risk of harvesting a trumpeter swan. Lastly, based on the characteristics of the hunters surveyed, any education should include distance estimation, swan identification, and a review of current regulations.

Literature Cited

Banko, W. E., and R. H. Mackay. 1964. Our native swans. Pages 155-164 *in* J. P. Linduska, editor. Waterfowl Tomorrow. United States Fish and Wildlife Service, Washington, D.C., USA.

Dahlgren, R. B., A. Wywialowski, T. A. Bubolz, and V. L. Wright. 1977. Influence of knowledge of wildlife management principles on behavior and attitudes toward resource issues. Transactions of the North American Wildlife and Natural Resources Conference 42:146-155.

Dillman, D. A. 1978. Mail and telephone surveys: the total design method. John Wiley and Sons, New York, New York, USA.

Engelhardt, K. A. M. 1997. Evaluation of translocation criteria for trumpeter swans reintroduced to northern Utah: habitat quality and interactions with tundra swans. Thesis, Utah State University, Logan, USA.

Gratson, M. W., and C. Whitman. 2000. Characteristics of Idaho elk hunters relative to road access on public lands. Wildlife Society Bulletin 28:1016-1022.

Langenau, E. E. Jr., and P. M. Mellon. 1980. Characteristics and behaviors of Michigan 12- to 18-year-old hunters. Journal of Wildlife Management 40:69-78.

Limpert, R. J., and S. L. Earnst. 1994. Tundra swan (*Cygnus columbianus*). The Birds of North America, Number 89, A. Poole and F. Gill, editors. The American Ornithologists' Union, Washington, D.C., USA, and the Academy of Natural Sciences, Philadelphia, Pennsylvania, USA.

Luszcz, D., and C. Betsill. 1988. Evaluation of a tundra swan season in North Carolina. Proceedings of the Annual Conference of Southeast Association of Fish and Wildlife Agencies 42:388-395.

Mitchell, C. D. 1994. Trumpeter swan (*Cygnus buccinator*). The Birds of North America, Number 105, A. Poole, and F. Gill, editors. The American Ornithologists' Union, Washington, D.C., USA, and the Academy of Natural Sciences, Philadelphia, Pennsylvania, USA.

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

Olsen, R. E., and A. D. Afton. 2000. Vulnerability of lesser snow geese to hunting with electronic calling devices. Journal of Wildlife Management 64: 983-993.

Patten, M. A., and M. T. Heindel. 1994. Identifying tundra and trumpeter swans. Birding 26:306-318.

Pelizza, C. A. 2000. Winter site selection characteristics, genetic composition and mortality factors of the high plains flock of trumpeter swans. Pages 29-34 *in* R. Shea, M. H. Linck, and H. K. Nelson, editors. Proceedings and papers of the 17th Trumpeter Swan Society Conference. The Trumpeter Swan Society, Maple Plain, Minnesota, USA.

Phillips, J. C. 1911. A years collecting in the state of Tamaulipas, Mexico. Auk 28:67-89.

Tessmann, S. A. 2000. Pacific flyway committee perspective on RMP trumpeter swan restoration. Pages 67-73 *in* R. E. Shea, M. H. Linck, and H. K. Nelson, editors. Proceedings and papers of the 17th Trumpeter Swan Society Conference. The Trumpeter Swan Society, Maple Plain, Minnesota, USA.

United States Fish and Wildlife Service. 2000. Proposal to establish operational general swan hunting seasons in the pacific flyway. Environmental Assessment. United States Department of Interior, Washington, D.C., USA.

United States Department of Interior, and United States Department of Commerce. 1998. 1996 National survey of fishing, hunting, and wildlife associated recreation: Utah. Washington, D.C., USA.

Utah Division of Wildlife Resources. 2001. 2001-2002 Utah Waterfowl Proclamation. Department of Natural Resources, Salt Lake City, Utah, USA.

Table 3.1. Experience and characteristics of Utah swan hunters surveyed, 2000 - 2001.

Category	n	%
Hunted swans last year		
Yes	106	40
No	161	60
Days spent swan hunting last year		
1	20	14
1-5	81	55
>5	47	32
Days spent swan hunting this year		
1	78	40
2-5	96	49
>5	21	11
Weekdays spent hunting this year		
1	71	40
2-5	77	43
>5	30	17
Weekend days spent hunting this year		
1	64	36
2-5	62	35
>5	51	29

Table 3.1. Continued.

Category	n	%
Estimated swan harvest distance		
0-8 meters	3	2
9-18 meters	25	15
19-27 meters	34	20
27-37 meters	67	40
37-45 meters	32	20
>45 meters	5	3
Direction of swan flight at harvest		
To you	118	64
Parallel to you	55	30
Away from you	11	6
Size of flock		
Single Bird	32	18
Small Flock (< 10 swans)	119	67
Large Flock (> 10 swans)	26	15
Shotgun gauge		
10	37	14
12	214	80
<12	16	6

Table 3.1 Continued.

Category	n	%
Shell size		
8.89 cm (3.5 inch)	154	59
7.62 cm (3 inch)	89	34
6.99 cm (2.75 inch)	18	7
Number of companions hunted with		
0	26	10
1	97	37
≥2	138	53
Shots fired to harvest a swan		
1-3	86	63
4-5	24	17
6-10	28	20

CHAPTER 4

CONCLUSIONS

Species-specific flight trajectories could have a dramatic effect on relative vulnerability of trumpeter and tundra swans migrating through Utah. Though trumpeter swans are currently rare visitors to the state there has been increased pressure by some stakeholders to make the re-introduction of trumpeter swans to the area a priority (United States Fish and Wildlife Service 2000). This study sought to quantify the relative vulnerability of the two species based on previous flight dynamics research (Powell and Engelhardt 2000). The Utah Division of Wildlife Resources is interested in implementing a swan hunter education course to further reduce the vulnerability of trumpeter swans. However, little information is available regarding Utah swan hunters. I surveyed Utah swan hunters to determine if they would be receptive to such a course and to identify specific educational components of the course.

Swan Flight Dynamics

The flight dynamics theory predicts that trumpeter swans may be up to 26% more vulnerable to hunting mortality on a 3.8-km flight and 15% more vulnerable to hunting mortality on a 10-km flight than tundra swans in the same flight path. Assuming hunters are evenly distributed along the flight path of the swans, swans are traveling at optimal height and speed for their flight, and swans that are 30% larger appear 30% closer to the hunter, are shot at 30% more and are therefore killed 30% more often. This is difference in predicted vulnerability is due to a lower predicted height of flight and a larger body area for trumpeter swans than tundra swans. Some authors suggest that trumpeter swans may be more vulnerable to hunting than tundra swans because of behavioral factors (Gillette 2000). Trumpeter swans generally use smaller bodies of water and slightly deeper waters than tundra swans (Earnst 1994, Engelhardt 1997, Peliazza 2000). In addition trumpeter swans new to the area may not follow optimal flight trajectories as they search for resting and foraging areas. These naive swans are likely to be flying slower and lower than predicted in looking for foraging and resting areas which could increase their relative vulnerability.

In comparing predicted height and velocity of tundra swan flight to observed, predicted were higher than observed. The difference between predicted and observed heights can be explained by relaxing the assumption that I observed swans in mid-flight. To explain the difference between predicted and observed velocities, I took into account the possibility that the swans were flying at an angle, which would have caused a higher calculated velocity than the actual velocity of the swan. However, even if the swans were assumed to be flying at a 45° angle the difference could not be fully explained. This suggests either my model predicting velocity, or method for observing velocity was inaccurate. Predicted height were in good agreement with predictions if the swans were assumed to be landing no less than 500 m away from the observer, which suggests that trumpeter swans may be more vulnerable to indiscriminate hunting.

Swan Hunter Characteristics

The results of the swan hunter survey, however, suggest that most Utah swan hunters are experienced waterfowl hunters who are both interested and concerned about maintaining the current swan hunt as well as reducing the risks to trumpeter swans, and comply with regulations regarding checking harvested swans. The majority of swan hunters were aware of the morphological differences between trumpeter and tundra swans. In addition, most expressed a willingness to participate in a swan hunter education course, and complied with the current requirement to have swans checked at check stations. Those hunters who were interested in participating in the course were more likely to be members of conservation organizations, more aware of special interest group involvement, more likely to be successful in harvesting a swan, less likely to identify ease as a reason for participating in the swan hunt, and approved of the swan-permittee-only areas.

According to hunter responses the wounding rate for the swan hunt was 0.11 swans wounded per swan hunter, where the state of Utah estimates the crippling rate to be 0.17 (T. Aldrich, Utah Division of Wildlife Resources, personal communication). Swan hunters also were asked to estimate distances, 68% said a swan shilouette at 64 meters was out of range, and 75% said a swan shilouette at 77 meters was out of range. However swan hunters consistently underestimated distances to the swan, this is an area in which swan hunters could benefit from an education program.

The poor distance estimation may actually result in a decrease in the vulnerability between species. If both trumpeter and tundra swans are shot at throughout the portion of their flight spent in kill or wound range, then tundra and trumpeter swans would be equally vulnerable through a 3.8-km flight and trumpeter swans would be 8% more vulnerable through a 10-km flight.

Management Implications

If trumpeter swans become more common in Utah, then species-specific flight trajectories and differing sizes of the swans, coupled with differing behaviors and habitat use patterns of the two species could have a large impact on relative vulnerability. A swan hunter education course could contribute to decreasing the vulnerability of trumpeter swans during the general swan hunt. Most swan hunters in Utah would be receptive to this course.

A measure designed to minimize trumpeter swan vulnerability would be to manage areas in such a way as to encourage trumpeter swans to fly larger distances between foraging and resting areas. The flight dynamics theory prediction that swans fly higher on longer flights, coupled with the differences in habitat preferences of the two species of swan could be used to minimize trumpeter swan vulnerability. If the trumpeters need to travel longer distances, this might help reduce vulnerability by increasing portion of the flight spent out of range.

I would recommend that in addition to the swan hunter education course, managers implement a secondary measures to reduce trumpeter swan vulnerability.

Managers may wish to close certain hunting areas if trumpeter swans are consistently using the area.

In summary, a swan hunter education course should include modules on estimating harvest distances, good information on the differences between trumpeter and tundra swans, and hunting regulations. In addition, managers should be aware of the species-specific flight trajectories that may cause increased vulnerability for trumpeter swans, so that appropriate action can be taken and regulations can be implemented to reduce trumpeter swans vulnerability.

Literature Cited

Earnst, S. L. 1994. Tundra swan habitat preferences during migration in North Dakota. Journal of Wildlife Management 58:546-551.

Engelhardt, K. A. M. 1997. Evaluation of translocation criteria for trumpeter swans reintroduced to northern Utah: habitat quality and interactions with tundra swans. Thesis, Utah State University, Logan, Utah, USA.

Gillette, L. N. 2000. Perspectives of the Trumpeter Swan Society on Management of the Rocky Mountain Population of Trumpeter Swans. Pages 82-84 *in* R. Shea, M. H. Linck, and H. K. Nelson, editors. Proceedings and papers of the 17th Trumpeter Swan Society Conference. The Trumpeter Swan Society, Maple Plain, Minnesota, USA.

Pelizza, C. A. 2000. Winter site selection characteristics, genetic composition and mortality factors of the high plains flock of trumpeter swans. Pages 29-34 *in*

R. Shea, M. H. Linck, and H. K. Nelson, editors. Proceedings and papers of the 17th Trumpeter Swan Society Conference. The Trumpeter Swan Society, Maple Plain, Minnesota, USA.

Powell, J. A., and K. A. M. Engelhardt. 2000. Optimal trajectories for the short-distance foraging flights of swans. Journal of Theoretical Biology 204:415-430.

United States Fish and Wildlife Service. 2000. Proposal to establish operational general swan hunting seasons in the pacific flyway. Environmental Assessment. United States Department of Interior, Washington, D.C., USA.