Monitoring Habitat Use by Male Mute Swans in the Chesapeake Bay

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Abstract: We tracked male mute swans (*Cygnus olor*) ($n = 2$) in 2002 and in 2003 ($n = 3$) using Global Positioning System (GPS) in a 217,500-ha area of the Chesapeake Bay in Maryland. We quantified habitat use among four habitat categories (submerged aquatic vegetation, open water, shoreline, and upland) and between diurnal and nocturnal periods. Swans did not use habitats in proportion to their availability; they consistently used upland less often than what was available within their home ranges. Most use occurred within submerged aquatic vegetation (SAV) and open water, which typically were the most abundant habitat types. When SAV was used, most locations were within sparse to moderately dense vegetation (11%–70% horizontal coverage). Diurnal and nocturnal use of habitats was similar. Although the sample size in our study was small, we believe this information is representative of the mute swan population in Chesapeake Bay because ground observations confirmed GPS-marked individuals always were within flocks ranging from 30–400 individuals. Given that mute swans were found in SAV frequently and are known to feed on it, they may negatively impact SAV coverage in the Chesapeake Bay. Control of mute swans in the Chesapeake Bay may be considered a viable conservation strategy for SAV restoration.

Key words: Chesapeake Bay, *Cygnus olor*, GPS, habitat use, mute swan, satellite telemetry

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Mute swans (*Cygnus olor*) were introduced from Eurasia to many locations throughout the United States in the late 1800s primarily for aesthetic purposes as additions to parks, zoos, and private estates (Ciaranca et al. 1997). Consequently, breeding populations were established, especially along the Atlantic Coast (Ciaranca et al. 1997). One of the largest populations in the United States is found in the Maryland portion of the Chesapeake Bay. The origin of this population has been traced to five swans that escaped captivity in 1962 (Reese 1975). In 1987, Maryland had 264 swans, and by 1999, the population had increased to approximately 4,000 individuals (Hindman and Harvey 2004).

The rapid increase of mute swans in Maryland has raised concerns about their potential effects on the Chesapeake Bay ecosystem (Reese 1975, Hindman and Harvey 2004). Mute swans primarily consume submerged aquatic vegetation (SAV), including species such as *Ruppia maritima*, *Zostera marina*, *Potomogeton* spp., *Vallisneria americana*, and *Elodea canadensis* (Ciaranca et al. 1997). Mute swans consume large quantities of SAV, with estimates ranging from 1.8–3.6 kg wet SAV per swan per day (Willey and Halla 1972, Fenwick 1983). Submerged aquatic vegetation is a significant component of the Chesapeake Bay estuarine ecosystem. Seagrasses here are known to be particularly important as they support diverse epiphytic and microbial communities. They also provide structure and food, including fish and macroinvertebrates that live in SAV, for waterbirds, including waterfowl, colonial wading birds, seabirds, and some species of piscivorous raptors, and other wildlife (Thayer et al. 1975, Heck and Thoman 1984, Wyda et al. 2002). Waterbirds are also important in transporting energy and nutrients within the estuary and among littoral, marsh, and upland habitats (Erwin 1996). Biomass for SAV varies seasonally, with peak growth occurring July–October, and senesces by December (Moore et al. 2000).

Mute swans do not migrate from the Chesapeake Bay (Reese 1975); therefore, they may forage on SAV year-round (Perry and Deller 1996, Tatu et al. 2007a). Studies suggest that breeding pairs are less detrimental to SAV than large flocks of non-breeding mute swans whose densities are concentrated during foraging (Cobb and Harlin 1980, Tatu et al. 2007a). If mute swans forage on SAV in the Chesapeake Bay year-round, they could negatively impact its coverage and other species that depend on it.

Previous studies have documented the quantity of SAV consumed by mute swans (e.g., Willey and Halla 1972, Fenwick 1983) and SAV species preference (e.g., Berglund et al. 1963, Mathaisson 1973), but their association with SAV relative to other avail-

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able habitats has not been quantified. Therefore, we used Global Positioning System (GPS) satellite transmitters on mute swans to study habitat selection. The objectives of this study were to: (1) compare habitat use by mute swans to available habitat and (2) compare habitat use between diurnal and nocturnal periods in the Chesapeake Bay.

METHODS

Study Area

Our study was conducted during August 2002–January 2003 and August–October 2003 in east-central Maryland along the eastern shore of the Chesapeake Bay. As the largest estuary in the continental United States, Chesapeake Bay has a broad range of salinity and an extensive littoral zone, with diverse habitats (Meanley 1982). Our 217,500-ha study area included Talbot and Dorchester counties, Maryland (Figure 1), where high densities of mute swans occur (Hindman and Harvey 2004). This portion of Chesapeake Bay contains an interspersion of SAV beds, open water, irregular shorelines, and upland sites.

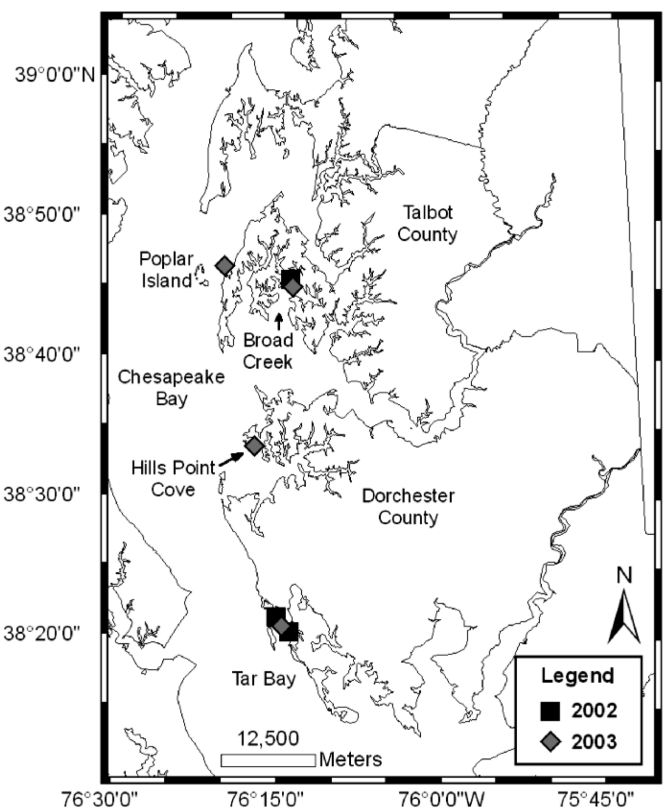

Figure 1. Chesapeake Bay study area in Talbot and Dorchester counties, Maryland, and capture sites of mute swans marked with satellite-tracked Global Positioning System transmitters in 2002 ($n = 3$) and 2003 ($n = 4$).

Telemetry

Each captured male mute swan was marked with a satellite transmitter containing a GPS unit (Microwave Telemetry, Inc.[3], Columbia, Maryland) in 2002 ($n = 3$) and 2003 ($n = 4$). Males were selected because they are usually larger than females (Ciaranca et al. 1997), thus presumably would be impacted less by the transmitter (150 g, 103 x 60 x 42 mm). On average, transmitters were 1.4% of the body weight of our swans. Swans from distinct flocks were captured late July through September while flightless during the annual molt using a swan pole (Minton 1968). Sex was determined by cloacal examination. Transmitters were attached using a backpack-style harness made with 9-mm teflon ribbon. Each swan was fitted with a white plastic neckcollar, imprinted with a unique black alphanumeric code, and a U.S. Fish and Wildlife Service aluminum tarsal band. To make general inferences about habitat use by mute swans, when possible, we performed two monthly observations of each marked bird from land to determine the extent that they were with flocks.

Data from transmitters were downloaded by satellite every three days and transmitted to the Argos Satellite Location and Data Collection System in Landover, Maryland. The duty cycle for transmitters was one GPS location per hour for ≤9 months. Location accuracy of the GPS unit was 0.01 minute (±14.5 m east-west and ±18.5 m north-south). Transmitter efficiency rates ranged from 66%–81% (mean = 73%, SE = 3%), where efficiency was the proportion of possible fixes producing a GPS location (Blouin et al. 1999). Locations were plotted in a Geographic Information System (GIS) with ArcView version 3.3 (Environmental Systems Research Institute, Inc., Redlands, California). Only locations recorded 14 days after transmitters were placed on swans were used in the analysis to allow transmitters to initialize and to allow birds to acclimate to the backpack.

Habitat Use

Habitat data included GIS layers for bathymetry and SAV distribution. A digital elevation map of bathymetric depths was acquired from the National Oceanic and Atmospheric Administration, U.S. Department of Commerce, Washington, D.C. The bathymetric layer was based on water depth data compiled from 1859 to 1993. For analysis, this layer was converted from raster (30 x 30 m cells) to vector format.

The GIS layers for SAV were compiled by the Virginia Institute of Marine Science (VIMS) to monitor the distribution of SAV in the Chesapeake Bay, its tributaries, and the Maryland and Virginia coastal bays of the Delmarva Peninsula (Orth et al. 2003).

3. Mention of trade names or commercial products does not constitute endorsement or recommendation by the U.S. government.

The methods used to create these layers are described briefly below and are explained more thoroughly in Orth et al. (2003). To create the SAV GIS layers, beds were digitized from aerial photographs and represented by polygons. Using detailed procedures with quality assurance and control measures for photo-interpretation, each bed was assigned a density class to indicate the extent of vegetation coverage. Density class was determined using a similar Crown Density Scale developed for estimation of tree-crown area in forests that has four categories: very sparse (0%–10% vegetation), sparse (11%–40%), moderate (41%–70%), and dense (71%–100%, Orth et al. 2003). These SAV surveys have been conducted by VIMS periodically since the late 1970s. We used the SAV surveys from 2002 and 2003.

Habitat use and availability were identified by overlaying swan data with SAV and bathymetric layers using ArcView. Habitat types for this analysis included the four categories of SAV, open water, shoreline, and upland. Locations were categorized by SAV density class if they fell within SAV beds. Locations with a water depth >0 m but not within SAV beds were classified as open water.

We used a standardized classification method for shoreline edges because the SAV and bathymetric layers were not completely concordant. Also, the 0.01-minute error associated with the GPS units and the resolution of the GIS layers prevented a more precise distinction between upland and water habitats. Locations <20 m from the shoreward edge of the bathymetric layer and SAV layer were classified as shoreline if there was no open water between the shoreward edge of the SAV and upland. If open water existed between the shoreward edge of the SAV and upland, then locations found in this area were classified as open water. Locations <20 m from this open water habitat also were classified as shoreline. All other locations were classified as upland.

To quantify habitat availability, a home range was estimated for each swan using the fixed kernel method (Worton 1989). Some authors (e.g., Boitani and Fuller 2000) caution against using home range to indicate habitat availability because all habitats may not be available to individuals. However, we assumed that the large number of locations obtained for each swan would produce stable home range estimates (Aebischer et al. 1993) with few areas unavailable to swans. A fixed kernel home range was calculated for each swan using Animal Movement Analysis Extension version 2.04 (Hooge and Eichenlaub 2000) to ArcView. *Ad hoc* smoothing factors calculated by this extension were used to estimate 95% probability contours for home ranges. Each home range was overlaid with the same GIS layers used to classify the locations. For each home range, the proportion of each habitat within the total area was determined and used to calculate the number of locations that would be expected to be in each habitat type, based on the number of locations collected for that swan within the contour.

Statistical Analysis

A chi-square test of homogeneity was used to determine whether the distribution of swan locations in used habitat was equal to the distribution of available habitat (Agresti 1990). Because of small counts for some cells, the *P*-values for each swan were calculated by simulation with 10,000 randomly drawn contingency tables, using the "chisq.text" function of the R programming language (R Development Core Team 2007). Each swan was tested individually to avoid pseudoreplication (Aebischer et al. 1993, Boitani and Fuller 2000) and to prevent the overrepresentation of swans with more locations in the data. We used an $\alpha = 0.05$ for all tests.

A Fisher exact test was used to determine if differences in habitat use existed between diurnal and nocturnal periods (Agresti 1990). During the months of this study, sunrise times varied from 0603 to 0722 hours and sunset times varied from 1658 to 2020 hours. Transmitters recorded locations at the turn of the hour (e.g., 1100, 1200, 1300); therefore, locations during the crepuscular hours (e.g., locations at 0600 and 0700 hours and 1700 through 2000 hours) were not included in this analysis. Locations collected from 0800 to 1600 hours were classified as diurnal locations and those collected from 2100 to 0500 hours as nocturnal locations.

Results

Transmitters and Home Range

Of the seven transmitters placed on swans, five lasted 32 to 143 days (Table 1). One transmitter malfunctioned in 2002 and provided no usable data. Another transmitter was only monitored for six days in 2003; a puncture in the casing destroyed it. The mean number of locations received per day from swans ($n = 5$) was 17.5 (SE = 0.7). Four of the five swans remained within 8 km of their capture sites; however, swan 9702 traveled nearly 24 km from the capture site (Table 1). Most locations were near shore, and no locations were over 1 km from shore. Although we were unable to re-sight the marked swans, GPS locations confirmed that these swans were in flocks ranging from 30 to 400 swans that were sighted from shore. Distances between successive hourly locations varied but averaged 198 m (SE = 17 m, Table 1). When intervals without movement were omitted, the mean distance between locations was 226 m (SE = 22 m). The maximum distance between successive locations was approximately 3,800 m. Home ranges ranged from 181–1,071 ha (mean = 582 ha, SE = 185 ha).

Table 1. Summary of telemetry of five male mute swans marked with satellite-tracked Global Positioning System (GPS) transmitters from Aug 2002–Jan 2003 and Aug 2003–Oct 2003 on Chesapeake Bay, Maryland. The fixed kernel method was used to calculate home range.

Swan	Year marked	Capture location	Days tracked	*n* locations	Mean distance between hourly locations in meters (SD)[a]	Maximum distance from capture site (m)	Kernel home range (ha)	Transmitter efficiency rate (%)	*n* locations per day (SD)
9702	2002	Broad Creek	143	2,253	142 (219)	23,937	403	66	15.7 (5.5)
9802	2002	Tar Bay	72	1,146	238 (321)	5,067	980	66	15.9 (5.5)
3403	2003	Tar Bay	32	619	228 (405)	4,380	181	81	19.3 (5.3)
3503	2003	Poplar Island	37	684	205 (278)	6,044	277	77	18.5 (6.0)
9703	2003	Broad Creek	70	1,268	179 (274)	7,509	1,071	76	18.1 (5.9)

a. Distance between hourly locations was calculated only for those locations that were separated by one hour.

Habitat Use

In the study area in 2002, the total area of SAV was 7,710 ha with 6% classified as very sparse, 17% sparse, 64% moderate, and 13% dense. In 2003, the area of SAV was 3,010 ha with 7% categorized as very sparse, 49% sparse, 39% moderate, and 4% dense. For swans monitored in 2002 and 2003, approximately 47% (n = 2,845) of all GPS locations were associated with SAV; the remaining locations were in open water (32%, n = 1,930), on the shoreline (13%, n = 757) or on upland (8%, n = 438). By SAV density category, 37% (n = 2,224) of the GPS locations were in moderate SAV, 6% (n = 370) dense SAV, 3% (n = 191) sparse SAV, and 1% (n = 60) very sparse SAV.

When habitat use was examined for individual swans, use was not proportional to availability within home ranges (Figure 2). All swans appeared to use upland less than expected. Swan 9702 used shoreline, moderate SAV, and dense SAV more and open water less than was expected based on availability of habitats within its home range. Swan 9802 used shoreline and open water more than expected but used other habitats approximately in proportion to their availability. Swan 3403 was observed in open water more and moderate SAV less than expected; other habitats were used approximately in proportion to availability. Swan 3503 was located after the acclimation period on an island with no SAV; this swan used the available open water and shoreline habitats in proportion to availability. Swan 9703 used shoreline, moderate SAV, and dense SAV more than expected from available habitats within its home range.

No difference in diurnal or nocturnal habitat use was detected for three swans (swan 9802, $P = 0.16$; swan 3503, $P = 0.15$; swan 9703, $P = 0.37$). Swans 9702 ($P = 0.05$) and 3403 ($P = 0.03$) used some habitats differently diurnally versus nocturnally though differences were small in magnitude. Swan 9702 used upland and dense SAV at night more than during the day and shoreline and moderate SAV during the day more than at night. Swan 3403 used moderate SAV at night more than during the day and open water during the day more than at night.

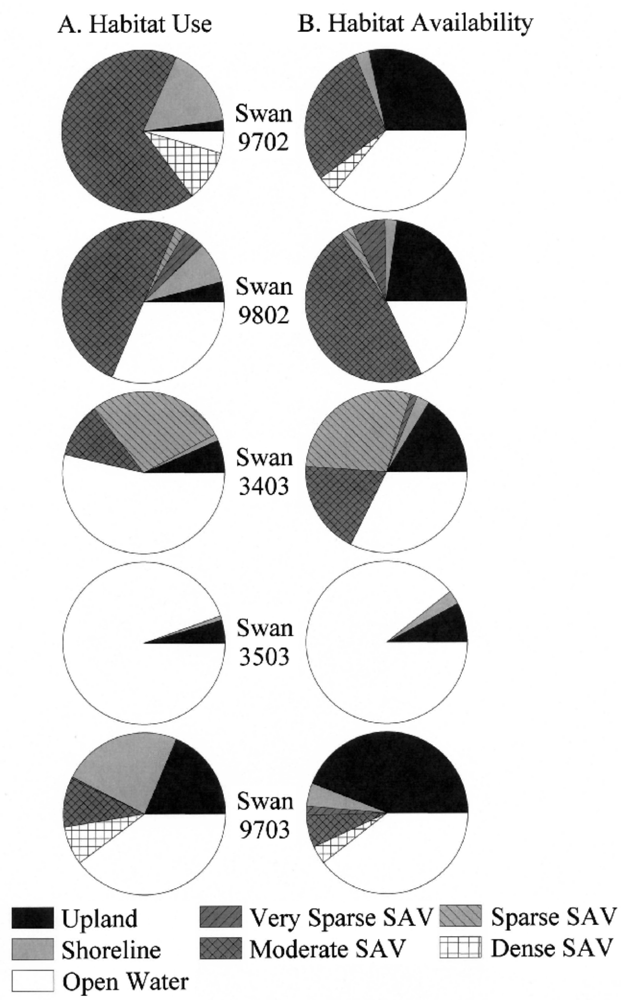

Figure 2. Habitat use (A) of five male mute swans with Global Positioning System transmitters on the Chesapeake Bay, Maryland. Available habitat (B) is based on habitat types located within a fixed kernel home range for each swan. Locations associated with submerged aquatic vegetation (SAV) were further classified by vegetation density (very sparse [1%–10%], sparse [11%–40%], moderate [41%–70%], and dense [71%–100%]).

Discussion

Mute swans use SAV in the Chesapeake Bay during the growing and senescent seasons. Across both years, 47% of observations were located in SAV. Although individual swan use of SAV varied, our rate of use is consistent with other studies (40%; Sears 1989, Tatu 2006). We believe the mute swans in our study likely represent typical habitat use in the Chesapeake Bay because ground observations confirmed our study birds always were associated with large flocks. Locations from tracked individuals indicate that flocks may remain in areas with SAV during the molt and winter months during peak growth, reproductive, and senescent periods for SAV. Herbivory during the growing season has been shown to reduce survival of SAV (Van Dijk et al. 1992). Further, swans forage on roots, stolons, and underground tubers by uprooting entire plants (Willey 1968, Owen and Cadbury 1975). It has been suggested that this constant foraging activity has the potential to reduce SAV beds in the Chesapeake Bay (Tatu et al. 2007a).

Consumption of SAV by large aggregations of swans may remove necessary food and cover for insects, fish, and shellfish and severely reduce available resources for native waterfowl (Reese 1975). With decreased availability of SAV in the Chesapeake Bay, waterfowl may have to shift their diet (Perry 1998) or alter their foraging behaviors (Perry and Uhler 1988). If this does not occur, reduced survival and reproduction could occur (Orth and Moore 1983). Allin et al. (1987) reported that mute swans may compete with other waterfowl species for SAV, especially during winter, when food resources are scarce.

We observed notable differences among years in SAV use by mute swans; use of SAV in 2003 (0–38%) was much lower than in 2002 (57–77%). One explanation may be the difference in SAV availability between years, which was nearly twice as great in 2002. Plants make up a large portion of the diet of mute swans, but when SAV is not available, they will consume algae and animal matter (Ciaranca et al. 1997, Perry et al. 2004). Swan 3503 lacked SAV in its home range, and we hypothesize that it likely subsisted on algae and invertebrates associated with Poplar Island. Thus, mute swans may be able to utilize other resources in the absence of SAV.

Mute swans utilized similar habitats at night as during the day. Time activity budgets indicate that mute swans feed 25%–44% of the day (Keane and O'Halloran 1992, Chasko 1986 in Ciaranca et al. 1997, Tatu et al. 2007b). We are unaware of time activity studies that have been conducted at night for mute swans, and this is an important research direction. If nocturnal feeding of SAV occurs, it will further emphasize the potential of this species reducing SAV density.

Many factors affect the quality of any habitat analysis, including the accuracy of locations and resolution of habitat layers. Global Positioning System telemetry has better location accuracy than very high frequency telemetry or re-sighting marked individuals (Kernohan et al. 1998). Even with location errors <20 m, classifying locations near the edge of habitats is problematic. We assumed that habitat did not affect acquisition of locations because all habitats were open, with minimal interference for satellite fixes. With regard to the resolution of the SAV layer, the positions of beds were accurate. However, the data represent a single snap-shot for the year, and SAV exhibits spatial and temporal variability both between and within years (Moore et al. 2000). Therefore, this variability was not captured in the SAV layer, and may have added to the variability in presumed habitat use among individual swans.

Exclosure studies have documented that mute swan herbivory reduces cover, shoot density, and canopy height of SAV in the Chesapeake Bay (Tatu et al. 2007b). Future research should focus on the relative impact of mute swans on SAV compared to other species and anthropogenic causes of degredation and loss of SAV in the Chesapeake Bay. Our telemetry study showed that marked mute swans do not use habitat in proportion to what is available in their home range and that they are primarily utilizing aquatic habitats and avoiding upland. An important consequence of their presence in aquatic habitats during critical periods for SAV is the potential negative impact to SAV and its restoration in Chesapeake Bay. Control of mute swans may be considered a viable strategy for SAV conservation and restoration.

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Literature Cited

Aebischer, N. J., P. A. Robertson, and R. E. Kenward. 1993. Compositional analysis of habitat use from animal radio-tracking data. Ecology 74:1313–1325.

Agresti, A. 1990. Categorical data analysis. Wiley-Interscience, New York, New York.

Allin, C. C., G. G. Chasko, and T. P. Husband. 1987. Mute swans in the Atlantic Flyway: A review of the history, population growth and management needs. Transactions of the Northeast Section of the Wildlife Society 44:32–47.

Berglund, B. E., K. Curry-Lindahl, H. Luther, V. Olsson, W. Rodiie, and G. Sellerberg. 1963. Ecological studies on the mute swan (*Cygnus olor*) in southeastern Sweden. Acta Vertebratica 2:167–288.

Blouin, F., J. Giroux, J. Ferron, G. Gauthier, and G. J. Doucet. 1999. The use of satellite telemetry to track greater snow geese. Journal of Field Ornithology 70:187–199.

Boitani, L. and T. K. Fuller, editors. 2000. Research techniques in animal ecology: Controversies and consequences. University of Columbia Press, New York, New York.

Chasko, G. 1986. The impact of mute swans on waterfowl and waterfowl habitat. Wildlife Investigation: Waterfowl Resources and Survey. W-49-R-10, Final Report, Connecticut.

Ciaranca, M. A., C. C. Allin, and G. S. Jones. 1997. Mute swan (*Cygnus olor*). *In* A. Poole and F. Gill, editors. The Birds of North America, No. 273. The Academy of Natural Sciences, Philadelphia, Pennsylvania, and The American Ornithologists' Union, Washington, D.C.

Cobb, J. S. and M. M. Harlin. 1980. Mute swan (*Cygnus olor*) feeding and territoriality affects diversity and density of rooted aquatic vegetation. American Zoologist 20:882.

Erwin, R. M. 1996. Dependence of waterbirds and shorebirds on shallow-water habitats in the mid-Atlantic coastal region: An ecological profile and management recommendations. Estuaries 19(2A):213–219.

Fenwick, G. H. 1983. Feeding behavior of waterfowl in relation to changing food resources in the Chesapeake Bay. Doctoral dissertation. Johns Hopkins University, Maryland.

Heck, Jr., K. L. and T. A. Thoman. 1984. The nursery role of seagrass meadows in the upper and lower reaches of the Chesapeake Bay. Estuaries 7(1):70–92.

Hindman, L. J. and W. F. Harvey, IV. 2004. Status and management of mute swans in Maryland. Pages 11–17 *in* M. C. Perry, editor. Mute swans and their Chesapeake Bay habitats: Proceedings of a symposium. U. S. Geological Survey, Biological Resources Discipline Information and Technology Report, USGS/BRD/ITR 2204-2005, Reston, Virginia.

Hooge, P. N. and W. Eichenlaub. 2000. Animal Movement Extension to ArcView, version 2.04. Alaska Science Center, Biological Science Office, U. S. Geological Survey, Anchorage, Alaska.

Keane, E. M. and J. O'Halloran. 1992. The behaviour of a wintering flock of mute swans *Cygnus olor* in southern Ireland. Wildfowl 43:12–19.

Kernohan, B. J., J. J. Millspaugh, J. A. Jenks, and D. E. Naugle. 1998. Use of an adaptive kernel home-range estimator in a GIS environment to calculate habitat use. Journal of Environmental Management 53:83–89.

Mathaisson, S. 1973. A molting population of non-breeding mute swans with special reference to flight-feather molt, feeding ecology and habitat selection. Wildfowl 24:43–53.

Meanley, B. 1982. Waterfowl of the Chesapeake Bay country. Tidewater Publishers, Centreville, Maryland.

Minton, C. D. T. 1968. Pairing and breeding of mute swans. Wildfowl 19:41–60.

Moore, K. A., D. J. Wilcox, and R. J. Orth. 2000. Analysis of the abundance of submersed aquatic vegetation communities in the Chesapeake Bay. Estuaries 23:115–127.

Orth, R. J. and K. A. Moore. 1983. Chesapeake Bay: An unprecedented decline in submerged aquatic vegetation. Science 222:51–53.

———, D. J. Wilcox, L. S. Nagey, A. L. Tillman, J. R. Whiting, and A. Serio. 2003. 2002 distribution of submerged aquatic vegetation in the Chesapeake Bay and coastal bays. Virginia Institute of Marine Science Special Scientific Report No. 139. Grant No. CB983649-01-0. Final report to U.S. Environmental Protection Agency, Chesapeake Bay Program, Annapolis, Maryland.

Owen, M. and C. J. Cadbury. 1975. The ecology and mortality of mute swans at the Ouses Washes, England. Wildfowl 25:31–42.

Perry, M. C. 1998. Wetland habitats for wildlife of the Chesapeake Bay. Pages 332–349 *in* S. K. Majumdar, E.W. Miller, and F. J. Brenner, editors. Ecology of Wetlands and Associated Systems. Pennsylvania Academy of Science, Easton, Pennsylvania.

——— and A. S. Deller. 1996. Review of factors affecting the distribution and abundance of waterfowl in shallow-water habitats of Chesapeake Bay. Estuaries 19:272–278.

——— and F. M. Uhler. 1988. Food habits and distribution of wintering canvasbacks, *Aythya valisineria*, on Chesapeake Bay. Estuaries 11(1):57–67.

———, P. C. Osenton, and E. J. R. Lhones. 2004. Food habits of mute swans in Chesapeake Bay. Pages 31–36 *in* M. C. Perry, editor. Mute swans and their Chesapeake Bay habitats: Proceedings of a symposium. U. S. Geological Survey, Biological Resources Discipline Information and Technology Report, USGS/BRD/ITR 2204-2005, Reston, Virginia.

R Development Core Team. 2007. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, www.R-project.org.

Reese, J. G. 1975. Productivity and management of feral mute swans in Chesapeake Bay. Journal of Wildlife Management 39:280–286.

Sears, J. 1989. Feeding activity and body condition of mute swan *Cygnus olor* in rural and urban areas of a lowland river system. Wildfowl 40:88–98.

Tatu, K. S. 2006. An assessment of impacts of mute swans (*Cygnus olor*) on submerged aquatic vegetation in Chesapeake Bay, Maryland. Doctoral dissertation. West Virginia University, Morgantown.

———, J. T. Anderson, L. J. Hindman, and G. Seidel. 2007a. Mute swans' impact on submerged aquatic vegetation in Chesapeake Bay. Journal of Wildlife Management 71(5):1431–1439.

———, ———, ———, and ———. 2007b. Diurnal foraging activities of mute swans in Chesapeake Bay, Maryland. Waterbirds 30(1):121–128.

Thayer, G. W., D. A. Wolfe, and R. B. Williams. 1975. The impact of man on seagrass systems. American Science 63:288–296.

Van Dijk, G., A. W. Breukelaar, and R. Gijlstra. 1992. Impact of light climate history on seasonal dynamics of a field population of *Potamogeton pectinatus* L. during a three year period (1986–1988). Aquatic Botany 43:17–41.

Willey, C. H. 1968. The ecological significance of the mute swan in Rhode Island. Transactions of the Northeastern Wildlife Conference 25:121–134.

——— and B. F. Halla. 1972. Mute swans of Rhode Island. Rhode Island Department of Natural Resources, Division of Fish and Wildlife, Wildlife Pamphlet, No. 8.

Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70:164–168.

Wyda, J. C., L. A. Deegan, J. E. Hughes, and M. J. Weaver. 2002. The response of fishes to submerged aquatic vegetation complexity in two ecoregions of the mid-Atlantic Bight: Buzzards Bay and Chesapeake Bay. Estuaries 25(1): 86–100.