

# Status, Distribution, and the Future of Bald Eagles in the Chesapeake Bay Area

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**Abstract.**—The Chesapeake Bay plays a significant role in the life cycle of Bald Eagles (*Haliaeetus leucocephalus*) along the entire Atlantic coast of the U.S. In addition to supporting a resident breeding population, the Chesapeake Bay is an area of convergence for post-nesting and subadult Bald Eagles from breeding populations in the southeastern and northeastern U.S. The convergence of three geographically distinct populations (northeast, southeast, and Chesapeake Bay) suggests that the Bay plays a particularly important role in the recovery of Bald Eagles in eastern North America. Since the ban on DDT and formal listing under the Endangered Species Act, the Chesapeake Bay breeding population has increased dramatically. Between the early 1970s and 2001 the population within the Bay and vicinity has grown exponentially from 60 to 646 pairs with an average doubling time of just over eight years. Reproductive rates have increased over this time period and are now similar to those documented prior to the DDT era. With the current rate of increase, the population is expected to reach saturation within the next decade. Bald Eagles continue to be vulnerable to the potential introduction of new biocides into the estuary, human disturbance within nesting and foraging areas, and the loss of habitat to urban and industrial development. The tidal fresh reaches of the estuary appear to support core breeding areas, as well as, concentration areas for migrant populations and should be priorities for long-term conservation efforts.

**Key words.**—Bald Eagle, *Haliaeetus leucocephalus*, Chesapeake Bay, breeding population, migrant populations, recovery, current threats, ecological requirements.

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The United States Fish and Wildlife Service (FWS) originally listed the Bald Eagle (*Haliaeetus leucocephalus*) as federally endangered on 11 March 1967 under the Endangered Species Protection Act of 1966 (16 U.S.C. 668aa-668cc) and subsequently under the Endangered Species Act of 1973 (16 U.S.C. 1531 *et seq.*). The primary reason cited for the original listing was broad-scale population declines linked to dichloro-diphenyl-trichloroethane (DDT) and associated reproductive failure. To facilitate the recovery of the Bald Eagle, the FWS divided the lower 48 states into five recovery regions. The Chesapeake Bay (including portions of Virginia, Maryland, West Virginia, Pennsylvania, Delaware, and New Jersey) is one of these recovery units. Since the ban on DDT in 1972, Bald Eagle populations have increased dramatically across much of the lower 48 states (Millar 1999). During a periodic population review, the FWS determined that specific reclassification goals had been reached as outlined in regional recovery plans. Bald Eagles were formally reclassified from “endangered” to “threatened” on 12 July 1995 (60

FR 36000). On 6 July 1999, the FWS published an Advance Notice of Intent (ANOI) to remove the Bald Eagle from the list of endangered and threatened wildlife (64 FR 36453). After no action was taken on this notice, the FWS on 16 February 2006 again published an ANOI to remove the Bald Eagle from the list of endangered and threatened wildlife (71 FR 8238). Since its passage in 1973, the Endangered Species Act (ESA) has been the lead legislation protecting the Bald Eagle and its habitat in the United States. If removed from the federal list of threatened and endangered species, the Bald and Golden Eagle Protection Act (BGEPA) (16 U.S.C. 668-668d) will become the lead legislation protecting the Bald Eagle population. As interpreted in the Notice (71 FR 8238) and the subsequent definition of terms (71 FR 8265) protection of Bald Eagles and their habitats under the BGEPA will be very similar to that provided under the ESA.

The Chesapeake Bay is the largest estuary in the United States and one of the most productive aquatic ecosystems in the world. The Bay plays a significant role in the life cycle of

Bald Eagles along the entire Atlantic Coast including three federal recovery units (Chesapeake Bay, Northern, and Southeastern). In addition to supporting a resident breeding population, the Chesapeake Bay is an area of convergence for post-nesting and sub-adult Bald Eagles from breeding populations in the Southeast and Northeast. In late spring and early summer, eagles migrate north from Florida and other southeastern states to spend the summer months in the Bay (Broley 1947; Wood *et al.* 1990; Millsap *et al.* 2004). In the late fall, eagles migrate south from populations in New England and the maritime provinces of Canada to spend the winter months on the tributaries of the Bay (McCullough 1986). The convergence of three geographically distinct populations (northeast, southeast, and Chesapeake Bay) suggests that the Bay plays a particularly important role in the recovery of Bald Eagles in eastern North America.

In this paper, we provide a synthesis of available information on the resident breeding population of Bald Eagles within the Chesapeake Bay, as well as the use of the Bay by migrant populations from the north and south. Efforts to study and manage Bald Eagles within the Chesapeake Bay span more than 50 years. We draw information from work done primarily in Maryland and Virginia. Together, these two states support >90% of the breeding population within the broader Chesapeake Bay recovery region.

## BREEDING POPULATION

### Historic Breeding Population

No specific estimates of the Chesapeake Bay Bald Eagle population are available prior to the early 1900s. However, given the high productivity of Bay waters and the availability of extensive shallow-water foraging areas, it has been speculated that prior to European settlement the Chesapeake Bay may have supported one of the densest breeding populations of Bald Eagles outside of Alaska. By applying breeding densities from Alaska to the extensive Chesapeake Bay shoreline, Fraser *et al.* (1996) suggest that the pristine Chesapeake

Bay may have supported in excess of 3,000 breeding pairs of Bald Eagles. This estimate highlights the productivity of Bay waters but includes the simplifying assumption of no spatial variation in breeding density.

A recent investigation of the relationship between the Bald Eagle breeding population and salinity has shown that colonization rate, breeding density, and reproductive rates declined significantly with increasing salt concentrations (Watts *et al.* 2006). Breeding density was four-fold higher along tidal fresh reaches of the Bay compared to polyhaline reaches. Based on the "behavior" of the population between 1977 and 2002, differences in colonization are expected to increase rather than decrease as the population approaches capacity. One implication of these results is that the initial carrying capacity of the Bay may have been approximately half of that projected by the Fraser *et al.* (1996) study.

The first recorded survey of Bald Eagles in the Chesapeake Bay was a ground survey conducted by Bryant Tyrrell for the Audubon Society in 1936 (Tyrrell 1936). Tyrrell's survey covered approximately 25% of the available habitat within which he estimated 150-200 nesting pairs (although he actually documented only 71 nests). This survey has been used to project that the Chesapeake Bay population was between 600 and 800 breeding pairs at this time (Abbott 1978a; Byrd *et al.* 1990).

### Breeding Population Decline

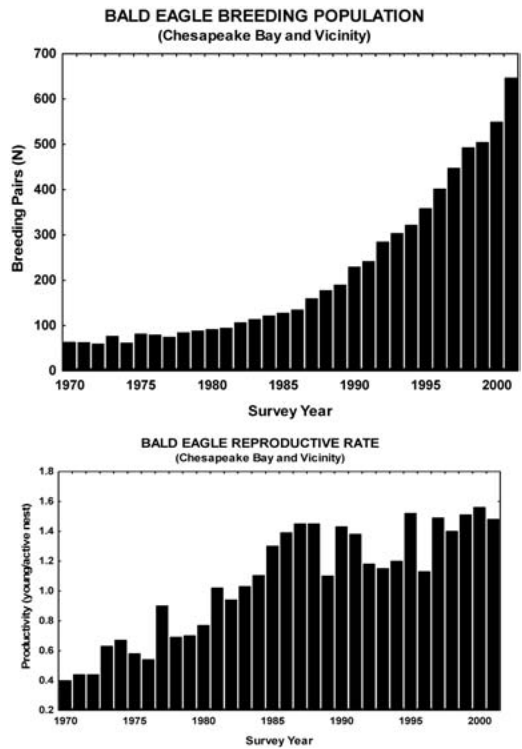
There are no records during the early phases of the Chesapeake Bay Bald Eagle population decline that lead to any quantitative assessment of either the rate and duration of the decline or the causal factors. Many factors (e.g., land clearing, hunting and collecting, overfishing, market hunting for waterfowl, land development) likely contributed to declines in the population prior to and after the Tyrrell surveys (Fraser *et al.* 1991). However, the decline in the Chesapeake Bay Bald Eagle population was evident to the ornithological community by the mid-1950s (Abbott 1957, 1959). This time period coincides with the parallel awareness of an

ongoing decline in Florida that was hypothesized by Broley (1957, 1958) to be caused by the widespread use of the biocide DDT. DDT and several related compounds came into widespread use as pesticides in the mid-1940s. We now know that the primary cause of the most recent and deepest phase of the population decline was the presence of DDT and its metabolites DDD and DDE in the Bald Eagle's food chain (Wiemeyer *et al.* 1972, 1984). Residue levels of several organochlorine pesticides found in eggs from the Chesapeake Bay Bald Eagle population in the years 1973-1979 were some of the highest for any Bald Eagle population in the United States (Wiemeyer *et al.* 1984). Analysis of carcasses during this time period indicated that this region's population was one of the most contaminated populations in the United States (Byrd *et al.* 1990).

The first aerial survey of eagle nests in the Chesapeake Bay was conducted in 1962 (Abbott 1963). The survey included approximately twice the land area covered by Tyrrell in 1936. Survey results suggested that about 150 breeding pairs of eagles remained in the Chesapeake Bay in 1962 (Abbott 1978a). Annual aerial surveys continued to document a decline until the population reached an estimated low of approximately 60 pairs in the early 1970s (Abbott 1978b).

### Breeding Population Recovery

Since reaching a low in the early 1970s the Chesapeake Bay Bald Eagle population has exhibited a rapid recovery with an overall ten-fold increase in breeding pairs (Fig. 1, top). This increase has been exponential with an average doubling time of just over eight years (Watts *et al.*, in press). This rate of growth is comparable to that experienced by other populations within the portion of the breeding range where the species has been federally listed. During the 15-year period between 1982 and 1997, average growth rate within the conterminous United States was 8.6% (Buehler 2000). The Chesapeake Bay population has now recovered to the size estimated during the 1930s (Tyrrell 1936; Abbott 1978a). Population size thresholds out-



**Figure 1.** (Top) Results of annual aerial surveys for breeding Bald Eagles within the Chesapeake Bay and vicinity (1970-2001) (top) Survey results presented here include the tidal reaches of Maryland and Virginia. Values presented represent documented occupied territories. The population has grown exponentially over this time period and exceeded recovery goals. (Bottom) Reproductive rates of Bald Eagles within the Chesapeake Bay and vicinity (1970-2001) as recorded during annual aerial surveys. Survey results presented here include the tidal reaches of Maryland and Virginia. Values presented represent the number of young recorded per breeding attempt.

lined in the Chesapeake Bay Bald Eagle Recovery Plan (Byrd *et al.* 1990) for federal "downlisting" (175-200) and "delisting" (300-400) were met in 1988 and 1992, respectively, for the broader Chesapeake Bay Recovery Region (Millar 1995, 1999).

Given the tremendous forward momentum currently exhibited by the breeding population, it seems likely that Bald Eagles will reach saturation within the Bay in a relatively short period of time. By fitting population growth data (1977-2002) for birds in portions of the lower Chesapeake Bay to a logistic curve, Watts *et al.* (2006) estimated that the population had reached approximately

70% of capacity by 2002. We believe that the Bald Eagle population within the Chesapeake Bay and vicinity is currently approaching 900 breeding pairs. In 2003, the population included 773 occupied territories (Watts and Byrd 2003; GDT, unpubl. data). Although Maryland ended annual monitoring surveys after the 2004 breeding season, average growth rates for years leading up to this time suggest further expansion. Continued annual monitoring in Virginia has documented continued growth in the lower portion of the Bay (Watts and Byrd 2005).

### Reproductive Rates

Within the Chesapeake Bay, Bald Eagle reproductive rates have varied over the period of population decline and recovery. Documented rates for the Chesapeake Bay population reached an all-time low of 0.2 chicks/breeding attempt in 1962 (Abbott 1963). A reproductive rate of 0.7 chicks/breeding attempt has been believed to represent the threshold for population maintenance for Bald Eagles (Sprunt *et al.* 1973). Buehler *et al.* (1991a) estimated that 1.0 chicks/successful nest (equivalent to brood size) was required for population maintenance in the Bay. A reproductive rate of 1.1 chicks/breeding attempt was set as the recovery goal for the Chesapeake Bay population (Byrd *et al.* 1990). From the lows in the 1960s, productivity exhibited a steady increase throughout the late 1960s and early 1970s, reaching projected maintenance levels by the mid-1970s (Fig. 1, bottom). The population has met or exceeded the productivity target outlined in the recovery plan in every year since 1985 suggesting that the contaminant loads within the Bay that were responsible for reproductive suppression have been reduced. The reproductive rate documented by Tyrrell (1936) prior to the DDT era was nearly 1.5 chicks/breeding attempt. The population has achieved this rate in four of the five years between 1997 and 2001.

The current reproductive rate achieved by Chesapeake Bay eagles is comparable to or greater than those of other regions. The highest reproductive rates have been in Flor-

ida where nesting Bald Eagles produced 1.3 young per breeding pair during 1997-2001 (Millsap *et al.* 2002) and Wisconsin where eagles produced 1.3 young per occupied territory in the mid 1980s (Kozie and Anderson 1991). Productivity in the Rocky Mountain states has ranged from 1.0 to 1.2 young per nesting pair (Swenson *et al.* 1986; Kralovec *et al.* 1992). Reproductive rates in the Pacific Northwest were 0.9 young per occupied nest (Anthony *et al.* 1994; Watson *et al.* 2002). In Alaska, productivity (0.8 young/pair) was well below that in the Chesapeake Bay (Steidl *et al.* 1997). The lowest reproductive rate (0.13 young/pair) recorded in recent times was in Alaska on Prince of Wales Island (Anthony 2001). That low rate was attributed to high densities of nesting Bald Eagles. There is no indication in the Chesapeake Bay that nesting densities have reached the level of inhibiting reproductive rates. The rate of expansion of the breeding population within the Bay region is quite dramatic (Fig. 2).

### MIGRANT POPULATIONS

The Chesapeake Bay is an area of convergence for post-nesting and subadult Bald Eagles from breeding populations in the southeast and northeast. In late spring and early summer, eagles migrate north from Florida and other southeastern states to spend the summer months in the Bay (Broley 1947; Wood *et al.* 1990; Millsap *et al.* 2004). In the late fall, eagles migrate south from New England populations to spend the winter months on the tributaries of the Bay (McCollough 1986). The convergence of three geographically distinct populations (northeast, southeast, and Chesapeake Bay) suggests that the Bay plays a particularly important role in the recovery of Bald Eagles in eastern North America.

Bald Eagle "concentration areas" are locations where eagles congregate in numbers much higher than what may be accounted for by local breeding pairs and their offspring and that support one to several communal roosts. Due to the status of the Chesapeake Bay as both a summer and winter des-

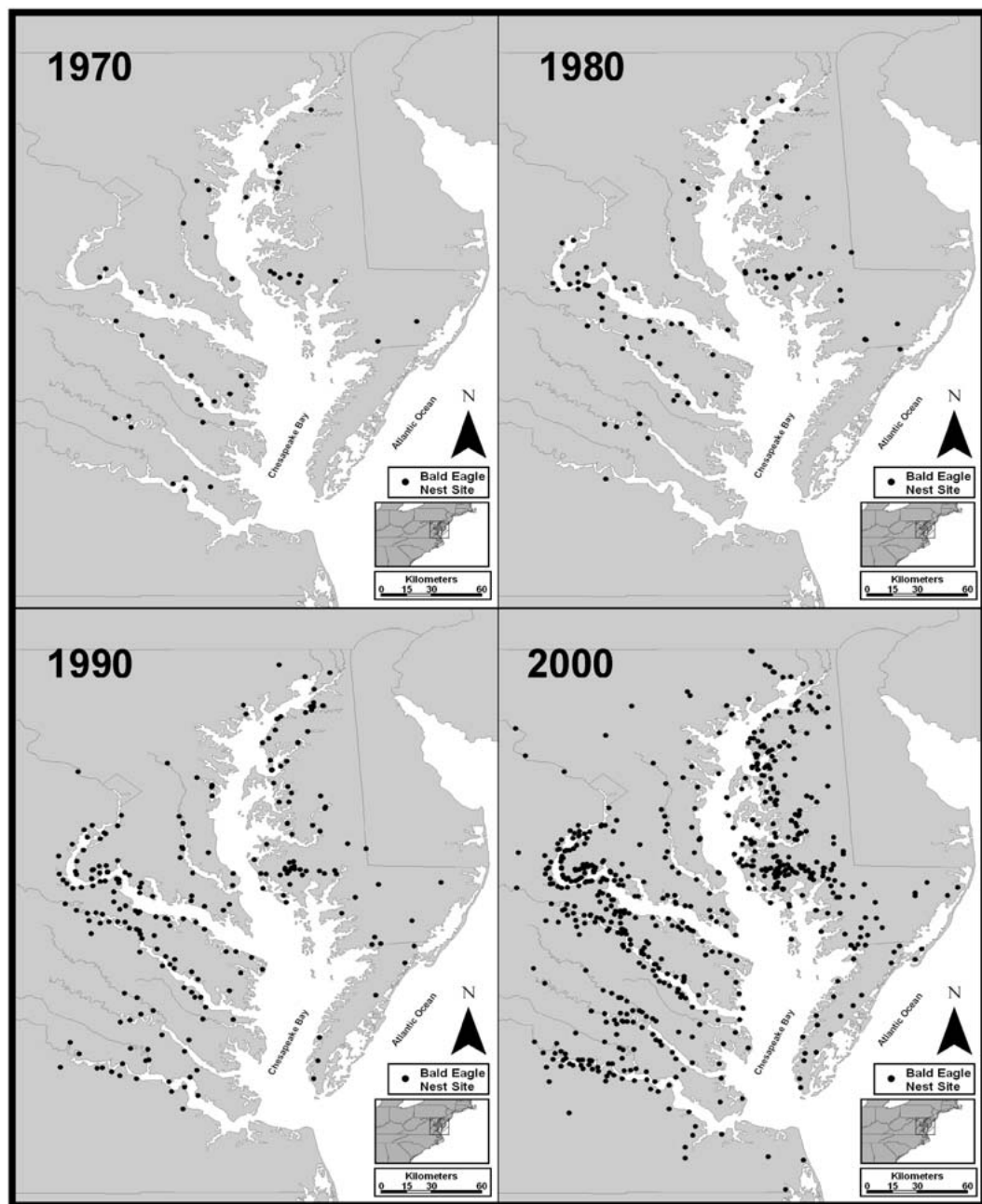


Figure 2. Maps of known Bald Eagle nests within the Chesapeake Bay of Maryland and Virginia 1970-2000).

tinuation for migrants, concentration areas may support a complex mix of individuals of different ages and from different populations. For example, during the summer months, concentration areas may support adults, sub-adults and young-of-the-year from the Chesapeake Bay population (some

of which may vacate their territories after breeding to move into concentration areas) and from the Southeast. Similarly, winter concentration areas may support non-breeding birds from the Chesapeake Bay and both reproductive and non-breeding birds from the Northeast. Because of this mix, it is diffi-

cult to determine how many birds are moving into the Bay from distant source populations. An additional problem is that there has been no definitive treatment of residency times/turnover rates of birds within concentration areas. For this reason, it is not possible to infer how many different individuals may be using particular concentration areas over an extended period of time.

### Summer Concentration Areas

The northward migration of Bald Eagles from Florida to the Chesapeake Bay was first documented during a review of band returns from the 1940s by Broley (1947). Broley showed that young birds banded in Florida as nestlings migrated north along the coast to the mid-Atlantic (or in a few instances further north). Definitive confirmation of these early findings has been obtained in recent years by Millsap *et al.* (2002) who used satellite telemetry to track 57 young eagles from Florida to their summer territories. Nearly 50% of these birds spent the summer in the Chesapeake Bay or coastal North Carolina. The birds returned to Florida for the winter months and established winter territories. What proportion of the southeastern populations (outside of Florida) migrate to the Bay for the summer is currently unknown. Observations of birds within several of these concentration areas (BDW, pers. obs.) implies that the migrants utilize the Bay not just as foraging areas but as a molting ground suggesting that the Bay plays an important role in their annual cycle.

Based on band returns and direct observations, Broley (1947) estimated that birds begin to leave Florida in April. This estimate was consistent with telemetry data obtained by Millsap *et al.* (2002). Migrant eagles appear to move into the Bay in early to mid-May. Use of concentration areas begins to rise during this period and reaches a peak between mid-June and mid-July (BDW and MAB, unpubl. data for lower Bay). In most years, numbers decline within concentration areas from mid-July through the end of September (BDW and MAB, unpubl. data for lower Bay). The timing of movements out of

the Bay is consistent with Broley's (1947) estimate from band recoveries of when birds return to Florida. Adults and sub-adults exhibit different schedules of migration and appear to have different residency periods within the Bay. Birds that move into the Bay in May are predominantly sub-adults. These birds are followed by adults such that the ratio of adults to sub-adults increases through the early summer and eventually reaches an approximate 1:1 ratio by the peak period. Age ratio shifts back toward a sub-adult bias through the early fall. Taken together, these patterns suggest that adults enter the Bay later and stay for a shorter period of time compared to sub-adults.

Migrant eagles are not distributed evenly throughout the Chesapeake Bay during the summer months. Since the early 1980s, six summer "concentration areas" have been identified and delineated that consistently support birds year after year. These include the upper James River (Scott 1971; Clark 1992; Watts and Factor 1994; Watts and Whalen 1997; Watts and Byrd 1999), the upper Rappahannock River (Portlock 1994; Watts 1998), the upper tidal Potomac River (including several sub-sites) (Wallin and Byrd 1984, Caledon State Natural Area unpubl. data, Mason Neck, NWR unpubl. data), the Pocomoke River (BDW, unpubl. data), the Nanticoke River (BDW, unpubl. data), and the upper Bay including Aberdeen Proving Ground (Millsap *et al.* 1983; Buehler *et al.* 1991b; SWCA, Inc. 1995). In addition to these somewhat stable concentration areas, it should be noted that eagles are very responsive to the distribution of prey and through the years ephemeral concentration areas have been documented that develop and disband in response to short-term food resources (BDW, pers. obs.).

In general, use of summer concentration areas has not been monitored as intensively as the breeding population. Peak counts of birds using the upper James River concentration area increased by a factor of five between 1982 and 1991 (Watts and Byrd 1999). This level of increase is generally consistent with the growth in the populations believed to utilize the Bay during summer. Collectively,

summer concentration areas within the Chesapeake Bay support a minimum of 1,500 birds. This composite number is based on peak Bald Eagle estimates within concentration areas during the mid-1990s from shoreline surveys. Peak counts include: James River (450), upper Rappahannock River (320), upper tidal Potomac River (500+), Pocomoke River (30), Nanticoke River (150), and the upper Chesapeake Bay including Aberdeen Proving Ground (100). How many total birds may pass through these areas during the summer months or what proportion of birds is from distant populations is unknown.

#### Winter Concentration Areas

Bald Eagles from northeastern Canada and the United States migrate southward into the Chesapeake Bay during the late fall and early winter period (Stewart and Robbins 1958; McCollough 1986; Byrd *et al.* 1990). These birds apparently move south in advance of large water bodies freezing over in northern latitudes and their appearance in the Bay coincides with the movement of waterfowl into the area. Numbers increase through November and December typically reaching a peak in January. Most northern birds are believed to have moved northward out of the Bay by late March.

As during the summer months, wintering eagles are not distributed evenly throughout the Chesapeake Bay. Several concentration areas have been described including the upper Chesapeake Bay (Aberdeen Proving Ground and lower Susquehanna River), Blackwater National Wildlife Refuge (NWR), Fishing Bay Wildlife Management Area, Pocomoke River, upper tidal Potomac River (Mason Neck NWR to Caledon Natural Area), upper Rappahannock River, upper James River, and the northwest corner of the Great Dismal Swamp NWR (Byrd *et al.* 1990; Fraser *et al.* 1991, BDW, unpubl. data; D. Schwab, Virginia Department of Game & Inland Fisheries, pers. comm.). In addition to these somewhat stable concentration areas, it should be noted that eagles are very responsive to the distribution of prey and through the years ephemeral concentration

areas have been documented that develop and disband in response to short-term food resources (BDW, pers. obs.).

As with summer concentration areas, winter concentration areas within the Chesapeake Bay have not been monitored with the same intensity as the breeding population. However, mid-winter surveys have been conducted in both Virginia and Maryland within selected concentration areas since 1979. Between 1986 and 2000 the number of birds within Maryland sampling areas increased at an annual rate of 5.4% (Steenhof *et al.* 2002). This increase is similar to that reported for Virginia of 4.5% between 1997 and 2000 (Steenhof *et al.* 2002). Both of these rates are considerably below those reported for the expected source populations. However, some specific sites have shown considerably higher increases in use than the overall state averages (e.g., Portlock 1994). The lack of correspondence between winter surveys conducted within the Bay and expected source populations may reflect the ongoing expansion of winter concentration areas beyond traditional survey routes. Efforts to re-define concentration areas are ongoing.

### ECOLOGICAL REQUIREMENTS

#### Breeding Habitat

Bald Eagles nest adjacent to or in the vicinity of large bodies of water. In the Chesapeake Bay region, eagles are known to nest along the ocean, inland bays, and reservoirs but the majority (>90%) nest along the shoreline of the Chesapeake Bay and its major tributaries. An examination of 367 historic nests in Virginia showed that greater than 95% of the nests were within three km of a channel at least 250 m wide and approximately 60% fall within one km of these waterways (Watts *et al.* 1994). This strong association with large waterways implies that the vast majority of habitats that support the current breeding population are contained within the narrow ribbon of land along the Chesapeake Bay shoreline.

Eagles within the Bay tend to nest in remote areas away from human development

(e.g., Andrew and Mosher 1982). In Virginia, the density of buildings and secondary roads is one of the best predictors of eagle nest distribution with densities being very low directly around nests compared to background densities. For 131 active nests that were examined in 1992, none had greater than five houses within 200 m or greater than ten houses within 400 m (Watts *et al.* 1994). In recent years, there has been an increasing number of eagle pairs nesting in close proximity to human activity.

### Nesting Substrate

Because eagles build large nests, they require large trees for nesting substrate. Due to their long wingspans, eagles typically choose large trees where they have direct flight access to the nest position. Nest trees are generally the largest trees in a woodlot, often towering over the surroundings and allowing the adult birds easy access to the nest. Under extreme circumstances, lack of available nesting substrate may limit nesting distribution (Hodges 1982). Because of their dual requirement for large trees and crown access, the actual relationship between eagle distribution and forest cover may be influenced by many factors (e.g., topography, landscape structure, forest composition). However, having trees substantial enough to support nests appears to be critical. An investigation of factors contributing to nest distribution in the lower Bay showed that landscapes surrounding eagle nests were significantly different from locations chosen randomly with respect to forest cover (Watts *et al.* 1994). On average, the land within 200 m of nests supported four times more mature forest than land surrounding random locations, suggesting that eagles do respond to the distribution of mature forests when selecting territory locations.

### Nesting Season

Within the Chesapeake Bay, Bald Eagle pairs typically remain on or near their breeding territories throughout the year (Buehler *et al.* 1991c). Nest building and repair begins

in October and peaks in mid-winter but may be observed during any month of the year (Fraser *et al.* 1991). Courtship flights and related behavior are most frequently observed during January and February and eggs are typically laid between mid-January and late February (outer ranges are mid-December through April). There is latitudinal variation in dates of clutch initiation with pairs on the James River laying four to six days earlier than pairs on the Potomac River (BDW, unpubl. data). Clutches vary in size between one and three eggs and are incubated by both sexes for 35 days. Most eggs hatch between early March and early May and eaglets remain in the nest for eleven to twelve weeks (Byrd *et al.* 1990).

### Prey Use

Bald Eagle diet varies seasonally according to prey availability and energetic demand. Throughout most of the Bay, diet appears to be dominated by fish during the summer months. During the brood-rearing period, eagle diet in the lower portion of the Chesapeake Bay is dominated (>95%) by fish (Wallin 1982; Markham 2004; Watts *et al.* 2004). In a recent intensive investigation (N = 730 identified prey) of prey delivered to nests, fish constituted 96.0% of prey, mammals 2.3%, reptiles 1.2% and birds 0.5% (Markham 2004). Catfish (*Ictalurus* spp.) and clupeids (i.e., shad and herring) were the dominant prey groups accounting for more than 70% of all prey items identified. Although not as well documented, there is some evidence that diet during the brood rearing period on the lower Delmarva Peninsula has a much greater avian component (Cline 1985; BDW, pers. obs.). Although they represent a relatively small portion of the overall diet, the use of turtles as prey is widespread throughout the Bay (Cline and Clarke 1982; GDT, personal observation). Collections of turtle shells from nests between 1977 and 1981 suggested that Diamondback Terrapins (*Malaclemys terrapin*) and Musk Turtles (*Sternotherus odoratus*) were the most frequently used species with Eastern Mud Turtle (*Kinosternon subrubrum*), Snapping Turtle

(*Chelydra serpentina*) and Eastern Box Turtle (*Terrapene carolina*) also represented. Working in the upper Bay, Mersmann (1989) showed that non-breeding eagles primarily used Gizzard Shad (*Dorosoma cepedianum*), Channel Catfish (*Ictalurus punctatus*), American Eel (*Anguilla rostrata*), and Atlantic Menhaden (*Brevoortia tyrannus*) during the summer and further that these species were the most abundant in gill-net samples. Observations of over-summering eagles within the James River concentration area suggest that the diet is predominately fish (100% of 221 prey items) (Watts and Whalen 1997).

During the late fall and winter, Bald Eagles in the Bay exhibit a dietary shift to more birds and mammals. This shift appears to reflect a reduction in the availability of fish in shallow-water foraging areas and the movement of winter-resident birds (primarily waterfowl and gulls) into the estuary (Mersmann 1989). De-Long *et al.* (1989) assessed prey availability with gillnet sampling and found that fish numbers in the upper Bay declined seasonally November through March while waterfowl abundances peaked in winter months until April. Haines (1988) collected prey remains under communal roosts on the upper tidal Potomac and found that birds represent a considerable portion of the diet during the winter months. This is consistent with analysis of pellets from several roost locations within the upper Bay during a similar time period (Mersmann 1989). It should be noted that diet studies based solely on prey remains show a bias towards birds and mammals (Mersmann *et al.* 1992). The diverse assemblage of bird remains collected from nests during the 1980s throughout the Bay likely reflect prey taken in late winter rather than during the spring brooding period (Cline 1985).

### Communal Roosts

Non-breeding Bald Eagles within concentration areas are typically very gregarious. Rather than roosting individually, birds often form communal roosts where several to several hundred individuals roost together within a relatively confined space. Within the Chesapeake Bay, communal roosts have been

identified that support several to well over 100 birds during different periods of the year (e.g., Wallin and Byrd 1984; Haines 1988; Buehler *et al.* 1991b; BDW unpubl. data).

Although communal roosts have been identified within different situations throughout the Chesapeake Bay, most sites share some physical characteristics (BDW, pers. obs.). Most sites 1) are positioned close to major foraging areas, 2) are isolated from human disturbance, 3) contain suitable substrate for roosting, and 4) when applicable, are positioned in areas protected from harsh weather. Another characteristic that seems to be common among roost sites is a clear movement corridor between the roost and primary foraging areas. Substrates include both pines and/or hardwoods. Actual roost trees tend to be large with good crown access for entry and exit. This typically means that they are supercanopy trees or are along some type of habitat edge (e.g., tree edge along a field, waterway, or marsh). Roosts have also been known to form within stands of dead snags over flooded marshes or beaver ponds.

The use of communal roost sites depends on several factors such that sites may form and be used for variable lengths of time. Bald Eagles are very opportunistic foragers and concentrated food patches that are ephemeral may lead to the formation of communal roost sites that may only be used for a couple of days. In contrast, sites that are strategically located within stable concentration areas may be used for many years. Concentration areas that depend on seasonal prey bases have communal roosts that are seasonal in use (BDW, unpubl. data). Because the location of roost sites depends not only on the characteristics of the site itself but also on the distribution of prey, changes in site characteristics, the surrounding landscape, or the distribution of foraging areas may all influence site use. The distribution of communal roosts in the lower Chesapeake Bay has been documented to shift rapidly in response to changes in the distribution of both prey and supercanopy trees (BDW, unpubl. data). Chronic disturbance within primary foraging areas has also been shown to change roost use (BDW, unpubl. data).

## CURRENT THREATS TO CHESAPEAKE BAY BALD EAGLES

### Habitat Loss

The availability of undeveloped waterfront property has become the dominant limiting factor for Bald Eagles in the Chesapeake Bay. Human activity is the best predictor of eagle distribution within the tidal portion of the Bay. Indicators of human activity such as housing and road density, shoreline use, and boating activity have been related to nest distribution (Watts *et al.* 1994), shoreline use (Buehler *et al.* 1991b; Watts and Whalen 1997), and the likelihood of nest abandonment (Therres *et al.* 1993) or recolonization (BDW, unpubl. data). Since Bald Eagles began their most dramatic decline in the 1950s, the human population within the tidal reach of the Bay has increased by more than 50% (Forstall 1996). A preliminary review of development occurring around eagle nests in the lower Chesapeake Bay shows that development had occurred in 55% of shoreline areas by the late 1980s (Byrd *et al.* 1990). Similarly, Buehler *et al.* (1991c) found that in northern areas of the Bay, 75.6% of the shoreline had developments within 500 m. Application of a habitat suitability model to the James River in 1991 revealed that more than 50% of the available area was not suitable for eagle breeding due to human use (Watts *et al.* 1994).

Increases in the human population around the Chesapeake Bay are expected to continue for the foreseeable future (Gray *et al.* 1988) likely causing further reductions in the capacity of the Bay to support Bald Eagles. In the long term, the size and stability of the breeding population will depend on both the Bald Eagle's capacity to cope with human activity and the management community's ability to protect suitable breeding habitat. Over the past decade, the transition in the eagle population has been ongoing with an increasing number of pairs breeding in very disturbed settings. However, a recent study of Virginia breeding pairs showed that only a small fraction of the overall population nested in urbanized landscapes (Watts

2006). More than 80% of the population nested in areas with less than 1% impervious surface in management buffers. Only 5% of pairs nested in areas with more than 2% impervious surface. The study also concluded that pairs breeding in areas with the highest coverage of impervious surface, were at least as productive as other pairs in the population. These results are generally consistent with a recent study in Florida showing that productivity and young survivorship were not influenced by the location of the breeding territory relative to urban development (Millsap *et al.* 2004). However, the long term impact of continued land development within the Bay on the Bald Eagle breeding population remains unclear.

### Human Disturbance

During particular stages of the nesting cycle Bald Eagles are very sensitive to human disturbance around nest sites. Depending on the specific site and pair, even minor disturbance may cause a loss of feeding opportunity, loss of eggs or small chicks due to exposure, or complete abandonment. Chronic disturbance may cause complete abandonment of the site. Activity around nest sites is regulated by Bald Eagle management guidelines (Cline 1985) implemented on a state level. Violations of these guidelines that result in a "taking" are subject to prosecution under appropriate laws. However, we currently have no information on the extent to which human disturbance is impacting the Chesapeake Bay breeding population. Given the rate of population growth in the recent past, there is no indication that disturbance has been limiting. However, this pattern may change as both human and eagle populations continue to increase.

Since the 1980s, Bald Eagles have shown an increasing tendency toward cohabitation with humans throughout the Chesapeake Bay. Nesting pairs now occur within residential neighborhoods, golf courses, cemeteries, parks and other lands that regularly receive high rates of human activity. Although many of these pairs have successfully raised broods, the extent to which they are self sus-

taining has not been evaluated. No differences were found in productivity between rural and urban nesting pairs in Florida (Mill-sap *et al.* 2004). Bald Eagles within the Chesapeake Bay have also been shown to be tolerant of noise. On the upper Chesapeake Bay, nesting Bald Eagles were unaffected by ordinance testing (Brown *et al.* 1999). Pairs have nested successfully in close proximity to active airport runways, interstate highways, rock quarries, and firing ranges (BDW and MAB, pers. obs.). One pair has successfully nested alongside the Woodrow Wilson Bridge just outside Washington, D.C. (GDT, personal observation), one of the busiest bridges in the Bay area.

Eagles foraging along the shoreline are very susceptible to human disturbance within the immediate uplands and within approximately 200 m of the associated waterway. An intensive study of eagle-boat interactions including more than 2,500 observations within the James River Concentration Area showed that the probability of a bird flushing from the shoreline increased as a boat approached (Watts and Whalen 1997). Flushing probabilities were less than 5% beyond 300m, increased to more than 20% as the boat reached 200 m, 45% as the boat reached 150 m, nearly 80% as the boat reached 100 m, and 90% as the boat reached 50 m. The immediate consequence of flushing birds from foraging areas is the loss of foraging opportunity.

Because Bald Eagles avoid contact with humans, consistent human activity may prevent eagles from using locations. For this reason, chronic human disturbance within potential foraging habitat will effectively render those areas unsuitable and prevent eagles from accessing prey populations (McGarigal *et al.* 1991). Over time, this loss in access to resources will serve to reduce the capacity of the area to support eagles and the population would be expected to decline to a new equilibrium within the remaining landscape. For non-breeding birds, this loss will result in a reduction in use of both the shoreline and associated communal roosts as birds are forced to focus activities in other areas. This represents a loss of foraging habitat

for migrant populations during the non-breeding period of their annual cycle. For breeding birds, this loss may result in nest failure and ultimately in territory abandonment, potentially leading to a reduction in the local breeding population.

### Contaminants

Due to their position as a top predator, Bald Eagles will always be vulnerable to contaminants that are introduced into the aquatic food chain. Exposure to organochlorine pesticides was the primary cause for the decline in Bald Eagles during the 1950s and 1960s (Byrd *et al.* 1990). Dieldrin caused direct mortality of adults and subadults and DDT/DDE greatly reduced hatching rates and productivity (Wiemeyer *et al.* 1984, 1993). Survival and successful reproduction of Bald Eagles in the Chesapeake Bay requires that eggs contain no more than two ppm DDE, 0.3 ppm dieldrin, and five ppm PCBs (Wiemeyer *et al.* 1984, 1993). Eggs collected after they failed to hatch in the 1970s contained mean concentrations of ten ppm DDE, one ppm dieldrin, and 25 ppm PCBs plus other organochlorine pesticides and their metabolites (Wiemeyer *et al.* 1984). These concentrations were among the highest in the species range. Concentrations were much reduced during the 1980s (Wiemeyer *et al.* 1993). Lead poisoning has been linked to the death of four eagles within the Bay region (Byrd *et al.* 1990). Other contaminants such as carbamate and organophosphate pesticides have been documented in several eagle deaths in Maryland and Virginia (U.S. Fish and Wildlife Service, unpubl. data).

### Disease

Diseases represent the largest source of non-anthropogenic mortality for eagles in the Chesapeake Bay. Historically, most of this mortality resulted from eagles eating winter waterfowl that died during outbreaks of avian cholera. These are periodic natural events that have almost certainly killed eagles throughout time. More recently, the spread of West Nile Virus into the region has

posed a risk to the population. Mortality due to West Nile Virus has been documented in the Chesapeake Bay population (Virginia Department of Game & Inland Fisheries, unpubl. data). The overall impact that this disease is currently having and will have in the future is unknown. Since 1994, a previously unknown disease called avian vacuolar myelinopathy has killed significant numbers of birds in Arkansas and South Carolina (National Wildlife Health Center 2000). This disease has not been documented as far north as Virginia. Based on current understanding of the modes of transmission it does not appear likely that this disease will enter the Chesapeake Bay population.

#### CONCLUDING REMARKS

As one of the most productive aquatic ecosystems along the Atlantic Coast, the Chesapeake Bay is important to both resident and migrant Bald Eagles. The breeding population has exhibited tremendous recovery and has exceeded population goals set forth in the federal recovery plan. The population remains vulnerable to the introduction of new chemicals and diseases into the ecosystem but current reproductive rates suggest a healthy population. Loss of habitat to urban expansion has replaced biocides as the greatest threat to the future of the population. Although the number of pairs nesting within urban setting is increasing, they still represent a small fraction of the overall population and their relevance to population persistence remains unclear. The tidal fresh reaches of the estuary support the highest density of breeding pairs, as well as, the largest concentrations of migrants from other populations. These relatively small areas represent the core of eagle activity within the Bay and should be the focus of future conservation efforts.

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