Delmarva Peninsula Fox Squirrel

(Sciurus niger cinereus)

5-Year Review:
Summary and Evaluation

September 2012

U.S. Fish and Wildlife Service
Chesapeake Bay Field Office
Annapolis, Maryland

Executive Summary:
2012 Delmarva Peninsula Fox Squirrel 5-Year Review

The Delmarva Peninsula fox squirrel (*Sciurus niger cinereus*), generally called the Delmarva fox squirrel (DFS), was listed as federally endangered in 1967 because of concerns about a reduction in distribution to only 10 percent of its historical range. Three recovery plans have been written for this species, with the most recent completed in 1993. This 5-year status review summarizes information obtained since the previous 5-review (USFWS 2007) and evaluates the status of the species' populations, habitat, and threats. It considers delisting criteria specified in the most current recovery plan and conducts an assessment of the five listing factors to determine the appropriate classification of this species under the Endangered Species Act (ESA).

Since the time of listing, the DFS's distribution has expanded from 4 to 10 counties, and its range now extends over 28 percent of the Peninsula. In Maryland, for instance, the DFS occurred on 103,027 acres of forest in 1990 and occurs on nearly 135,000 acres now. This range expansion is a result of both the establishment of 11 populations through translocations and the discovery of new or previously unknown populations. Eight new populations were described in the 2007 status review, and new sightings between these populations further connect DFS into larger, more secure populations. Using the acres of occupied forest and average density estimates of DFS for the different counties, we estimate that there are approximately 17,000 to 20,000 DFS distributed across the species' current range.

The DFS inhabits mature forests of mixed hardwoods and pines in the agricultural landscapes of the Delmarva Peninsula. Large trees in mature forests provide abundant food as well as cavities for dens. LiDAR data were used to quantify and map the acres of mature forest available to this species in the eight Maryland counties where information was available. This analysis indicates that 403,000 acres of mature forest exist in these counties and are distributed within and outside the current range. Although not all mature forest is suitable DFS habitat, forest maturity is the major feature determining potential habitat. Riparian areas provide many corridors that connect mature forest blocks. A dispersal model was developed to assess the connectivity of patches of forest across the Peninsula. The resulting maps indicate that the existing forests provide a reasonably well connected network of forest tracks to facilitate expansion of DFS populations.

A population viability analysis (PVA) developed for the DFS determined that a population of 130 DFS had a 5 percent chance of extinction in 100 years. This value has been referred to as a minimum viable population (MVP). Because it considers only demographic factors and not non-demographic threats, MVP is not a recovery goal; however, it provides useful information for assessing the demographic extinction risk of various DFS subpopulations (defined as population groups that are separated by distances greater than 2.25 miles from other groups or are isolated by rivers or other physical barriers). An analysis of 22 subpopulations indicates that approximately 85 percent of DFS are found in four large subpopulations that are only narrowly separated and are likely to expand and become even more connected. Each of these four subpopulations currently contains several times the MVP threshold of 130 squirrels.

The five-factor analysis of threats is a central component of this review. This analysis focuses on the effects of habitat loss from development, sea level rise, and timber harvest. Threats were examined by first looking at how they have affected DFS in the past 40 years, then projecting how they are likely to affect DFS in the next 20 to 40 years. Overall, these threats were not found to rise to the level of posing either a current or foreseeable risk of DFS extinction for the following reasons:

- Development is not a threat because most of the future residential development will occur around several large cities outside the DFS range. Current laws and programs are pushing development into agricultural land and out of forest land; moreover, the rate of land protection is much faster than development.

- Timber harvest is not a threat because the total acres of timber harvest and the size of individual cuts are decreasing over time, and LiDAR data indicate that sufficient acres of mature forest have remained on the landscape even from past harvest rates. In addition, 58,000 acres of forest land previously managed for pulp wood and thereby precluded from becoming DFS habitat will now be managed by the State of Maryland for sawtimber and wildlife values.

- Despite the fact that sea level rise has been occurring for the last 100 years and will eventually impact over 30,000 acres of occupied forest in southwestern Dorchester County in Maryland, it is not considered to be a threat because the associated habitat losses will occur in the largest extant subpopulation of DFS and is not expected to cause extirpation of this subpopulation. Even if the projected habitat loss were to occur immediately, this DFS subpopulation, which is over 70 times the minimum viable population size, would be very likely to persist. This subpopulation's current expansion into the interior of the Delmarva Peninsula is expected to continue. In addition, 80 percent of the squirrel's range is not vulnerable to sea level rise.

- Based on a long track record, we anticipate that State laws and programs in Maryland, Delaware, and Virginia, which have increased in strength over the past 40 years, will continue to conserve forest habitat and wildlife, including the DFS, should it be delisted.

In summary, the DFS is now sufficiently abundant and well distributed to withstand future threats. Its distribution currently provides good representation of the range of habitats where it historically occurred, and there is security in the redundancy of occupied forest patches. The large sizes of the DFS subpopulations also provide great resiliency to losses that might occur from sea level rise or any other threats, with each occupied area holding the potential to repopulate other individual patches should DFS be locally extirpated for any reason. Overall, our analysis of the threats indicates that the DFS is not in danger of extinction throughout all or a significant portion of its range and that it is not likely to become endangered within the foreseeable future.

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1.0 GENERAL INFORMATION

1.1 Reviewers

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1.2 Methodology Used to Complete the Review

This 5-year review was developed by the U.S. Fish and Wildlife Service's (USFWS or Service) Chesapeake Bay Field Office (CBFO) staff. Dr. Cherry Keller, the lead biologist and primary author, was assisted by members of the Delmarva Fox Squirrel Recovery Team and State partners. Leslie Gerlich, CBFO Geographic Information System (GIS) specialist, conducted most of the GIS analyses and obtained the GIS data layers used. Data for this review were solicited from interested parties through a Federal Register notice announcing initiation of this review on August 4, 2010; an August 7, 2010, article in a local newspaper; and direct emails and calls to State partners and Recovery Team members. Data were provided by staff of the Maryland Department of Natural Resources (MDDNR), the Delaware Department of Natural Resources and Environmental Control (DEDNREC), the Virginia Department of Game and Inland Fisheries (VDGIF), members of the Recovery Team, and other experts. On March 29, 2011, a Recovery Team meeting was held to discuss portions of the draft 5-year review, obtain comments on the approach, and seek additional information. On July 7, 2011, a draft review was sent to the Recovery Team and others for technical review; their input has been incorporated into this document.

1.3 Background

This review assesses the status of the Delmarva Peninsula fox squirrel (*Sciurus niger cinereus*), commonly called Delmarva fox squirrel (DFS), based primarily on information that has become available since the last revision of the Delmarva Fox Squirrel Recovery Plan (USFWS 1993). It augments the 2007 review (USFWS 2007), which concluded that the status of this species had greatly improved and that the DFS was nearing recovery. At that time, most of the threats to this species were not considered to constitute a risk of extinction. However, the existing information regarding timber harvest raised concerns about some portions of the squirrel's range, albeit timber harvest data at the time were acknowledged to be inadequate. The 2007 review concluded that the species' status should be considered threatened until further information could be obtained to better understand timber harvest and the availability of mature forest.

Over the past several years, CBFO has collected additional information on mature forest availability and timber harvests; in addition, more information has become available on other threats (e.g., sea level rise). The following analysis constitutes the second formal 5-year review for the DFS and updates the five-factor analysis. Although this review supersedes the 2007 review, it both references and provides summary information from that document. For instance, the DFS distribution data used in the previous review were current as of the end of 2005, whereas the distribution discussion in this review incorporates information through June 2010.

This 5-year review is intended to be a comprehensive evaluation of whether there are factors that could place the DFS in danger of extinction now or in the foreseeable future. The analysis has been conducted in conformance with 5-year review guidance issued by the Service's Headquarters Office (USFWS 2006).

1.3.1 Federal Register notice announcing initiation of this review

75 FR 47025 (August 4, 2010): Initiation of 5-Year Reviews of Five Listed Species: Delmarva Peninsula Fox Squirrel, Northeastern Bulrush, Furbish Lousewort, Chittenango Ovate Amber Snail, and Virginia Round-Leaf Birch.

1.3.2 Listing history

FR notice:	32 FR 4001
Date listed:	March 11, 1967
Entity listed:	Subspecies
Classification:	Endangered

1.3.3 Associated rulemakings

Experimental nonessential population designated for Assawoman Wildlife Management Area (WMA) (translocation) in Sussex County, Delaware. September 13, 1984 (49 FR 35951)

1.3.4 Review history

The DFS was included in cursory 5-year reviews conducted for all listed species from 1979 to 1991, as follows:

1. May 21, 1979 (44 FR 29566) – review of all species listed prior to 1975

2. July 22, 1985 (50 FR 29901) – all species listed before 1976 and in 1979-80, resulting in a 1987 notice of completion (no change) on July 7, 1987 (52 FR 25522)

3. November 6, 1991 (56 FR 56882) – all species listed before 1991

The first comprehensive and species-specific 5-year review for the DFS was completed in 2007 (USFWS 2007). In addition, the Delmarva Fox Squirrel Recovery Plan, including revisions and an update (see section 1.3.6 below) has included assessments of this species' status.

1.3.5 Species' Recovery Priority Number at start of 5-year review: 15C

1.3.6 Recovery Plan

Name of plan: Delmarva Fox Squirrel (*Sciurus niger cinereus*) Recovery Plan, Second Revision.
Date issued: June 8, 1993
Previous versions: Original recovery plan: November 6, 1979
First revision: January 1983
Plan update: October 31, 2003

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment (DPS) Policy

2.1.1 Is the species under review a vertebrate? Yes.

2.1.2 Is the species under review listed as a DPS? No.

2.1.3 Prior to this 5-year review, was the DPS classification reviewed to ensure it meets the 1996 policy standards? No.

2.1.4 Is there relevant new information for this species regarding the application of the DPS policy? Yes. New information, as presented in section 2.3.1 of this review, indicates that evaluation of evidence for potential eligibility for listing of population segments of DFS is merited. This analysis is presented below.

2.1.4.1 Summary of the 1996 DPS policy

Section 3 of the ESA defines "species" to include subspecies and "any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." In 1996, the USFWS and the National Marine Fisheries Service published a joint policy guiding the recognition of DPSs of vertebrate species (61 FR 4722). The DPS policy specifies three elements to assess whether a population segment may be recognized as a DPS, including: (1) the population segment's discreteness from the remainder of the species to which it belongs, (2) the significance of the population segment to the species to which it belongs, and (3) the population segment's conservation status in relation to the ESA's standard for listing (61 FR 4722). These criteria are hierarchical and must be considered in sequence; that is, the discreteness criterion must be met to evaluate significance, and both discreteness and significance must be established before considering a population segment's conservation status relative to listing. Therefore, we must first determine whether any DFS populations meet the DPS discreteness criterion.

2.1.4.2 Discreteness analysis
A population segment of a vertebrate species may be considered discrete if it satisfies either one of the following conditions:

1. It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors. Quantitative measures of genetic or morphological discontinuity may provide evidence of this separation.

2. It is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the ESA.

We have identified 22 subpopulations or areas of DFS occupied forest that are currently separated from each other by the 2.25-mile (mi) dispersal distance identified in the PVA (Hilderbrand *et al.* 2007) or physical barriers such as large rivers, as discussed in section 2.3.1.1.4 of this review. These areas are thought to be interbreeding groups of DFS that are reasonably separated from other such groups. However, it is clear from the changes in subpopulations identified in USFWS (2007) and this review that, over time, DFS have been found between subpopulations and that these discoveries are indicative of connectivity between subpopulations that were previously considered separate (see section 2.3.1.1.2). We anticipate that new DFS sightings between subpopulations will continue to at least some extent in the future, diminishing separation between most DFS subpopulations.

The most separate subpopulations would be those at the extremes of the range such as the Chincoteague and Prime Hook subpopulations and the Kent County translocations. We know these are not genetically distinct because they all resulted from translocations that began with at least some animals from Dorchester County (USFWS 1993). And a recent comparison of the genetic diversity of the translocated DFS to the genetic diversity of Dorchester County animals (Lance *et al.* 2003) indicates that they were similar and did not exhibit evidence of divergence. There is no other indication of any physical, physiological, ecological, or behavioral factors that are distinct between these subpopulations.

The analysis of the habitat connectivity and the distribution of DFS provided in Figure 10 of this review do suggest that barriers such as the Choptank River separate the Southern Talbot subpopulation from the Dorchester Nanticoke subpopulation at some points. However, even these subpopulations eventually connect further north where the Choptank River narrows into branches of the Tuckahoe River.

Chincoteague is probably the most isolated subpopulation because it is on an island. However, DFS have expanded from their original translocation site and are now occupying woodlots to the north, and, again, the source of these animals comes from the Dorchester County population. Their isolation is an artifact of the location of the Refuge where management could be assured to focus on this species and does not represent any long-term isolation.

For all of the reasons stated above, we do not consider there to be any discrete population segments that should be further considered for their significance or status.

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan containing objective, measurable criteria? Yes.

2.2.2 Adequacy of recovery criteria

2.2.2.1 Do the recovery criteria reflect the best available and most up-to-date information on the biology of the species and its habitat?

No. More recent information on the squirrel's distribution, subpopulation delineation, and population persistence is not reflected in the 1993 recovery criteria. Nonetheless, these criteria continue to act as generally appropriate measures of recovery.

2.2.2.2 Are all of the relevant listing factors addressed in the recovery criteria?

No. None of the recovery criteria specifically addresses any of the five listing factors, although habitat-related threats are alluded to. The criteria evaluate the biological status of the species.

2.2.3 List the recovery criteria as they appear in the recovery plan, and describe how each criterion has or has not been met, citing information[1].

The 1993 DFS recovery plan states that "the long-range objective of the Delmarva fox squirrel recovery program is to restore this endangered species to a secure status within its former range." The plan provides seven criteria to assist in determining whether the DFS could be either reclassified to threatened or delisted; that is, when the first three criteria are met, the species could be considered for downlisting to threatened, and when all criteria are met, the species could be considered for delisting.

[1] Section 4(f) of the Endangered Species Act of 1973, as amended (ESA) directs us to develop and implement recovery plans for the conservation and survival of endangered and threatened species unless we determine that such a plan will not promote the conservation of the species. The ESA directs that, among other requirements for the plan, we incorporate objective, measurable criteria, which when met would result in a determination, in accordance with the provisions of section 4 of the ESA, that the species be removed from the list. However, listing reclassification must reflect determinations made in accordance with sections 4(a)(1) and 4(b) of the ESA. Section 4 (a)(1) requires that the Secretary determine whether a species is endangered or threatened because of one or more of five threat factors. Therefore, recovery criteria must indicate when we would anticipate that an analysis of the five threat factors would result in a determination that a species is no longer endangered or threatened. Section 4(b) requires that the determination be made "solely on the basis of the best scientific and commercial data available."

Thus, while recovery plans are intended to provide guidance to the Service, states, and other partners on actions for minimizing threats to listed species and ensuring their long-term viability and to define the criteria by which to measure progress toward recovery, they are not regulatory documents and cannot substitute for the analysis and listing determinations required under section 4(a)(1) of the ESA. Any determination to remove a species from the list made under section 4(a)(1) must be based on the best scientific and commercial data available at the time of the determination, regardless of whether that information differs from the recovery plan.

Criterion 1 (knowledge base): *"Ecological requirements and distribution within the remaining natural range are understood sufficiently to permit effective management."*

Considerable new information has been obtained about the DFS's distribution and ecological requirements. Although there will always be more to learn about this fascinating animal, we consider the available information sufficient to understand its distribution and ecological requirements and permit effective management, as listed below. <u>Thus, we consider this criterion to be met.</u>

- Current range and distribution: Based on a USFWS GIS (Figure 1). New sightings have been added to this database every year.

- Population persistence: Ninety-two percent of sites identified as occupied in 1971 continued to be occupied 30 years later (Therres and Willey 2005). Monitoring of "benchmark sites" (Dueser 1999). Persistence of DFS occupancy in 270 forest tracts occupied in 1990 (this review).

- Monitoring of reintroductions: Therres and Willey (2002). Data from Delaware and Virginia. New trapping and photo-monitoring surveys; see Table 1.

- Genetic variability of reintroductions: Similar to source populations (Lance *et al.* 2003).

- Habitat suitability: Revised Habitat Suitability model for use in the field (Dueser 2000). Use of LiDAR (Light Detection and Ranging) data to assess habitat (Nelson *et al.* 2003, Nelson *et al.* 2005). Development of LiDAR model and LiDAR GIS data layers to identify suitable habitat for eight Maryland counties. Habitat model for within-stand assessment of DFS use (Morris 2006).

- Analysis of forest connectivity: Lookingbill *et al.* (2010)

- Population viability analysis: Hilderbrand *et al.* (2005)

- Effects of timber harvest: Paglione (1996), Bocetti and Patee presentation (2003)

- Effects of fire for stand improvements at Chincoteague National Wildlife Refuge (NWR): Kulynycz (2004)

- Pre- and post-development monitoring: Followup monitoring of several sites (trapping reports).

Criterion 2 (population trends using benchmark sites): *"The following seven benchmark populations (six within the remaining natural range and the introduced Chincoteague NWR population) are shown, according to the protocol in Appendix E [of the 1993 recovery plan], to be stable or expanding based on at least five years of data: Maryland sites are Hayes Farm, Blackwater NWR- Jarrett Tract, Blackwater NWR-Egypt Road, Eastern Neck NWR, Wye Island NRMA, LeCompte WMA, and Virginia: Chincoteague NWR."*

The DFS Recovery Plan (USFWS 1993) indicates that the benchmark sites were intended to provide "long-term population data" and overall trends. Ultimately, a slightly different set of eight benchmark sites were monitored, and the resulting data were analyzed (Dueser 1999). The benchmark report compiles data from the following sites:

- Hayes Farm
- Blackwater NWR, Jarrett Tract
- Blackwater NWR, Egypt Road
- Prime Hook NWR (translocation site)
- Assawoman WMA (translocation site)
- Wye Island Natural Resource Management Area (NRMA)
- LeCompte WMA
- Chincoteague NWR (four main sites within Chincoteague).

The two Delaware translocation sites, Prime Hook and Assawoman, were added as benchmark sites, and the Eastern Neck translocation site was not analyzed in the benchmark report (Dueser 1999). The report concluded that the benchmark sites were stable over a 5- to 7-year period, and benchmark monitoring was ended. The benchmark protocol's focus on DFS use of nest boxes has since been viewed as an unreliable technique for population monitoring as it is too influenced by weather.

Since the completion of benchmark monitoring, we have collected additional data to better understand rangewide population trends. Therres and Willey (2005) conducted a repeat survey of DFS presence/absence at 101 sites surveyed by Taylor in 1971. Of the 65 sites occupied in 1974, 60 (92 percent) continued to be occupied 30 years later, and 11 new sites had been colonized; the rangewide population was thus considered stable to increasing at that time. As of 2010, DFS persisted on 91 percent of the forest acres (ac) noted as occupied in 1990 (Chart 1) and on over 32,000 ac of newly identified occupied forest. We have thus concluded that the range of this species has substantially increased over time. Although two of the translocation benchmark populations, Assawoman and Eastern Neck, have become extirpated in the last 10 years, overall, DFS remain extant within their previously known occupied forest, and their range is expanding.

In addition, trapping continues at some benchmark sites and provides further information on long-term population dynamics. Long-term data from several sites at Blackwater and Chincoteague NWRs indicate that population dynamics for DFS are generally very stable and that populations at both high and low densities tend to remain at that level over time; for example, three sites trapped at Chincoteague over 11 years maintained a similar level of DFS abundance; that is, the respective sites showed high, medium, and low abundance in 1990, 2002, and 2010 (Larson 1990, Pednault-Willet 2002, USFWS 2010). Further, DFS at the low density sites do not disappear in 1 year and return in the next; rather, DFS remain present in low densities every year. Long-term trapping at Blackwater NWR shows a similar pattern of long-term persistence, although there may be some changes in relative abundance. The Egypt tract at Blackwater NWR has very high densities, although these numbers have decreased somewhat in the past 10 years, while the Jarrett tract started at medium density and is increasing to some extent (Gould 2009). Although DFS in isolated areas (such as small islands) are vulnerable to extirpation, at most sites DFS show long-term persistence. Given this evidence, we consider this criterion to be met.

Chart 1. Comparison of DFS occupancy of 103,125 acres of Maryland forest in 1990 and 2010.

Occupancy change from 1990 to 2010	**Presence (+) or absence (0) in 1990 sample and as of 2010**	**Acres of forest (# of forest tracts)**	**Percentage of the original 103,093 ac in each occupancy status**
Persistence	(+, +)	94,221 ac (181 forest tracts)	91%
Extirpations	(+, 0)	1,233 ac (7 forest tracts)	1%
Uncertain	(+, ?)	7,671 ac (87 forest tracts)	8%
Discoveries or Colonizations	(0?, +)	32,227 ac (250 forest tracts)	
Continued Absence	(0,0)	Not measured	

Criterion 3 (translocation success): *"Ten new colonies are established within the species' historical range. Translocations that may contribute to this have already been conducted. An introduced population will be considered established when a) five or more years after the last release one or more lactating females and at least one other adult are captured on the area, or b) eight or more years after the last release, at least three fox squirrels are captured on the site and their condition indicates these are healthy."*

We now consider 11 new colonies to have been successfully established through translocation efforts (see Table 1), based on 6 to 19 years of post-release trapping results (Therres and Willey 2002), and on many sites DFS are now observed beyond the initial translocation property. In addition, we have conducted more recent trapping and/or camera surveys to continue monitoring the persistence of these translocations, as discussed under Criterion 5 below. This criterion has been met.

Criterion 4 (new populations): *"Five post-1990 colonies are established, as defined by the criteria in condition 3, outside of the remaining natural range. These colonies will occupy various habitats and will represent an extension of the present range of the Delmarva fox squirrel."*

Eight new populations were identified in the 2007 review (Figure 2). These are:

- Northeastern Dorchester County, Maryland
- Southeastern Caroline County, Maryland
- The Tuckahoe River corridor in Talbot County, Maryland
- Northern Queen Anne's County (Chino Farms), Maryland
- The Centreville area of Queen Anne's County, Maryland
- The Kings Creek area of Talbot County, Maryland
- Northern Somerset County, Maryland
- Nanticoke WMA, Sussex County, Delaware

The new population discovered in southwestern Sussex County represents the first population found in Delaware since the time of listing that was not a result of a translocation. Since the 2007 status review, additional occupied forest has been discovered between some of these new populations, which improves their long-term likelihood of survival. For example, newly discovered occupied forested areas between the Dorchester and Nanticoke populations indicate that these two populations are now within dispersal distance of each other. Similarly, the Tuckahoe River corridor is now connected to the Centreville area through the discovery of additional occupied forest between these areas. This leads to the conclusion that these new populations are more secure than they were at the time of the 2007 review (see Criterion 5 below). Thus, this criterion has been met.

Criterion 5: (translocation persistence): *"Periodic monitoring shows that (a) 80% of translocated populations have persisted over the full period of recovery and (b) at least 75% of these populations are not declining."*

All 11 translocated populations identified in Criterion 3 have persisted over the full period of recovery and have grown in abundance on their release site and/or have expanded into new areas, and are thus not declining (see Table 1). Their initial success was documented solely by trapping techniques (Therres and Willey 2002); however, we now use trapping and/or camera surveys to document DFS persistence and expansion in the translocation areas, as discussed below.

Trapping and camera surveys conducted from 2009 to 2011 on the translocation sites show that DFS continue to persist, although their distribution at the site may have shifted. On some sites, DFS are found only on the original property where they were released, although they are now abundant and easily detected visually or by camera (e.g., Andelot Farm). In other cases, they have expanded beyond the original site (e.g., Harmony, Eby, and Prime Hook). In still other cases, they are no longer found on the original release site but have moved to nearby woodlands (Quaker Neck). We consider all of these scenarios to indicate persistence and growth of the population. Expansion beyond the release site is the ultimate intention of these translocations; however, keeping track of these expansions will be challenging. For instance, the Riggin translocation is in a large forest tract where it is difficult to observe DFS. The DFS have been trapped on site and observed over a mile from the original release site, but there are likely to be other areas where DFS have moved into that we have not yet documented. Overall, with the continued presence and expansion of DFS beyond the translocation sites, we consider this criterion to be met.

Criterion 6 (habitat protection mechanisms): *"Mechanisms that ensure perpetuation of suitable habitat at a level sufficient to allow for desired distribution (according to results obtained in condition 1) are in place and implemented within all counties in which the species occurs."*

There are several well-established programs that protect habitat from development (Rural Legacy, Maryland Environmental Trust, Maryland Agricultural Programs, etc.), and these programs, along with State and Federal ownership, currently protect an estimated 39,524 ac (29 percent) of DFS-occupied forest, as discussed in section 2.3.2.1.1 of this review. In addition, there are several State laws and regulatory programs that will continue to protect forest habitat. These include Maryland's Critical Area Law, Forest Conservation Act, and wetlands laws (see section 2.3.2.1.1). We thus consider this criterion to be met.

Criterion 7 (population management/connectivity): *"Mechanisms are in place to insure protection and monitoring of new populations, to allow for expansion, and to provide inter-population corridors to permit gene flow among populations."*

Habitat connectivity and protection are summarized briefly here. New LiDAR data indicate that mature forest is scattered throughout the Delmarva Peninsula and provides potential habitat for DFS to move into. Additionally, analysis of current forest distribution using the J-walk model (Lookingbill *et al.* 2010) indicates there is a good network of forest across the Delmarva Peninsula to connect dispersing DFS. As some examples, the translocations in the southern part of the Peninsula are in an area of very large and well-connected tracts of forest, there are connected pathways of forest that lead out of Dorchester County, and DFS are already connected to Caroline County through occupied forest along the Choptank River. Monitoring of DFS will continue, and new sightings will continue to be recorded in the CBFO GIS. We consider this criterion to be met.

2.3 Updated Information and Current Species Status

The following assessment focuses on the status of DFS populations within their current range in eight Maryland counties on the Eastern Shore, in Sussex County, Delaware, and on Chincoteague NWR in Virginia. The assessment is organized into four major sections, including biology (2.3.1.1), which covers changes in the range of this species, population dynamics and persistence within the range, and population viability analysis; habitat (2.3.1.2), which describes the basic land use of the Delmarva Peninsula, the abundance and distribution of mature forest habitat, the connectivity of that forest habitat, and the ownership patterns of that habitat; analysis of threats (2.3.2), which looks at trends over the past 40 years or so and projects future trends to evaluate likely effects in the foreseeable future; and synthesis of this information (2.4), which draws conclusions about the species' status. Note that Appendix A contains definitions of terms highlighted as bold text.

2.3.1 Biology and habitat

2.3.1.1 Life history, distribution, and abundance

2.3.1.1.1 Life history and detectability

The DFS is a subspecies of eastern fox squirrel found only on the Delmarva Peninsula. It is a large, silver-gray tree squirrel with white underparts and a wide tail. It can be distinguished from the gray squirrel (*Sciurus carolinensis*) – the only other tree squirrel in the area – by its larger size, short ears, general shape, and color (Appendix B).

The DFS inhabits mature forests of mixed hardwoods and pines within the agricultural landscapes of the Delmarva Peninsula. Large trees in mature forests provide abundant crops of acorns, pine cones, and other food as well as cavities for dens. Although it initially appeared that hardwoods (Dueser *et al.* 1988) and then pines (Dueser 2000) were most important for the squirrel, we now understand that the precise species composition is not consequential as long as forests provide a mix of pines and hardwoods and a variety of species of mature trees (Taylor 1976, Dueser *et al.* 1988, USFWS 1993, Dueser 2000). The DFS is also associated with forests that have a more open understory (Dueser *et al.* 1988, Dueser 2000) or where understory shrubs are clumped leaving other open spaces (Morris 2006). This may be because DFS spend considerable time on the ground and are slower and more deliberate in their movements than the gray squirrel (Dozier and Hall 1944) making them more vulnerable to predation in areas of thicker understory where visibility is lower.

Female DFS typically breed in late winter and have litters of 2 to 4 young, with most born from February to April (USFWS 1993). Den sites are frequently found in hollow portions of trees, but leaf nests may be used as well. As with most tree squirrels, DFS are polygamous and females raise the young by themselves. Females typically have their first litters when they are 1 year of age. The DFS has been known to live for 7 years (Dueser 1999), but a life span of 3 to 4 years is probably more typical.

Home ranges of DFS vary considerably, ranging from 6 ac for females at Chincoteague NWR (Larson 1990) to 74 ac in an agricultural setting (Flyger and Smith 1980). However, the home range averaged across all literature sources is approximately 40 ac, and home ranges of 30 to 40 ac were typical in other studies (Paglione 1996, Pednault-Willet 2002). Home ranges overlap, and reported density values range from a low of 0.15 DFS per ac to a high of 0.5 DFS per ac with an average of 0.33 DFS per ac; these numbers are based on mark-recapture estimates at Blackwater and Chincoteague NWRs (Paglione 1996, Pednault-Willet 2002).

While dispersal data are always difficult to obtain, individual animals are known to move as far as 5 mi in one direction, and marked animals have been observed to move 2.5 mi and return. However, most DFS do not move this far in their daily activities, and two studies, each with over 200 marked individuals, found that 97 percent of the marked animals remained within about 0.5 to 1 mi of initial capture locations (Dueser 1999, C. Bocetti and H. Pattee pers. comm. 2003). A population viability analysis for this species calculated an estimated **dispersal distance** based on home range size and concluded that populations that were within 2.25 mi of each other were likely connected. Although some DFS disperse greater distances, the **range**, or total area where

DFS are considered likely to occur, is defined as the area within 3 mi of forest tracts with verified DFS sightings.

Long-term trapping data indicate that population dynamics for DFS are generally very stable and that populations at both high and low densities tend to remain at these levels over time. For example, three sites trapped at Chincoteague NWR over many years have generally kept the same rank order of DFS abundance; for example, the same sites showed high, medium, and low abundance in 1990, 2002, and 2010 (Larson 1990, Pednault-Willet 2002, USFWS 2010). Further, DFS at the low-density sites do not disappear in 1 year and return the next; rather they remain present in low densities every year. Long-term trapping at Blackwater NWR shows a similar pattern, although there may be subtle changes over time in relative abundance. Blackwater's Egypt tract has had very high densities, although these numbers have come down somewhat in the past 10 years; conversely, the Jarrett tract started at medium density and is increasing to some extent (Gould 2009).

Studies suggest that DFS have high site fidelity and tend to shift home ranges rather than abandon a site in response to disturbance. Paglione (1996) tracked radio-collared DFS in Dorchester County, Maryland, before and after a 30-ac timber harvest conducted within a larger forested area. DFS with home ranges that overlapped the timber harvest simply shifted their home ranges into adjacent habitat (Paglione 1996). A second harvest of a 40-ac wooded peninsula surrounded on three sides by agricultural fields resulted in some DFS leaving the site; however, within the clearcut, two small islands of habitat were retained, and DFS were observed in these remnant habitats more than 10 years after harvest (Paglione 1996) and remained present as of 2010 (W. Giese pers. comm. 2010). This information also indicates that DFS are able to move through harvested areas to access other habitat, which is consistent with observations of DFS foraging in younger stands of regenerating trees.

Similar population stability in response to clearcuts was observed by Bocetti and Pattee at three study sites in Dorchester County (Bocetti and Pattee 2003). In the first 3 years after the timber harvest, DFS numbers remained the same as the pre-harvest period, in contrast to gray squirrels, which primarily left the site after harvest. Ten years after the clearcuts – when the openings had become filled with tall young saplings – DFS were still present, although the mean number of DFS in each site was about half the original number (C. Bocetti email 9/16/2009).

Thus, long-term data indicate that DFS occupancy of woodlots is fairly consistent over time. Presence of DFS in a woodlot in 1 year and again 5 or 10 years later implies that the squirrels are present in the interim years as well. These data indicate a DFS tendency for persistence and relative population stability in many locations, even when habitats are disturbed, providing additional support for the use of squirrel occupancy of woodlots as a reliable monitoring tool to assess the species' rangewide status.

The life history of the DFS has a bearing on which techniques are most appropriate for long-term monitoring. The DFS is quiet and secretive and cannot be readily observed in a casual walk through the woods or along a line-transect (Paglione 1996). They vocalize infrequently and can remain quiet and hidden. Still, DFS are often seen on the edges of fields and roadsides and in the woods by individuals who live, work, and hunt in the areas where they occur; for instance, DFS are often seen by hunters who remain still in tree blinds for several hours at a time. Their detectability on the landscape depends on the season and day and is not easily predicted. Therefore, people who are in the area frequently have the best chance of seeing them.

Experienced observers who can easily distinguish DFS from gray squirrels are our best source for determining where DFS are present and for delineating their current range. Other survey techniques, such as trapping and camera surveys, have provided important information for localized areas, but, ultimately, our understanding of the range of this species is derived primarily from reports of DFS sightings by knowledgeable observers. Thus, because of these aspects of its life history, the DFS's range and population dynamics are best understood through changes in its occupancy of forest tracts.

2.3.1.1.2 Changes in DFS range and distribution

Historically, this species was patchily distributed throughout most of the Delmarva Peninsula and into southern Pennsylvania and possibly New Jersey (Taylor 1976). It was extirpated from Delaware prior to 1920, and while not documented from Virginia, it is assumed to have occurred there in the distant past (Taylor 1976). In the 1940s the DFS was reported as present in seven Maryland counties (Dozier and Hall 1944), but by the time of listing, the remnant populations occurred in only four Maryland counties (USFWS 1993): Dorchester, Talbot, and Queen Anne's Counties, with a small population established in the 1920s on an island in Kent County (see Figure 1).

After listing, the hunting season was closed, and recovery efforts focused on broadening DFS distribution and decreasing its vulnerability to extinction, primarily through translocations. In addition, over the past 12 years, new populations have been discovered and there are now many more areas of forest known to be occupied by DFS. The squirrel's known range now covers ten counties: eight in Maryland and one each in Delaware and Virginia (see Figure 1). The **range** is currently delineated as the area within 3 mi of DFS sightings (Appendix A), covering 28 percent of the Delmarva Peninsula. Details about changes in the species' range follow.

Translocations: Since listing this species, translocating animals to establish new DFS populations within their historical range has been a major focus of the recovery program. In 1968 the first translocation was conducted at Chincoteague NWR; the DFS population there continues to thrive. Eventually 16 translocations were implemented, and 11 (69 percent) continue to support populations of DFS (see Table 1, Figure 2). At most of these locations, recent sightings also indicate that squirrels have moved beyond the release site and now occupy additional forest tracts adjacent to or near the original release sites. The Maryland translocations were supplemented with additional animals in the late 1990s, as recommended in the 1993 Recovery Plan; the Delaware translocations were not supplemented, which may have contributed to the loss of the Assawoman translocation and causes some concern for the Prime Hook NWR population. Trapping data from the Maryland sites indicate that the catch-per-unit-effort of DFS on reintroduction sites 6 years after supplementation was comparable to live-trapping results conducted within the natural range (Therres and Willey 2002). Recent trapping and camera surveys are also showing that DFS persist at these locations and are moving into new areas.

The success rate for the DFS translocations is substantially higher than is typically found for other translocation efforts for other species. A study of 116 reintroductions found that only 26 percent were classified as successful (Fischer and Lindenmayer 2000). The success rate is generally higher for mammals and wild source populations (Griffith et al. 1989, Wolf et al. 1996), such as the DFS translocations. A recent review of tree-squirrel reintroductions (including the DFS) found that successful translocations with this group can be accomplished with as few as 15 animals for some species and 35 for most species (Wood *et al.* 2007). Although there have been some initial concerns about genetic diversity of translocated populations, analysis indicates that the genetic diversity of translocated animals was comparable to that of the source populations (Lance *et al.* 2003). The success of the DFS translocations is a clear indication that this is a good conservation tool for this species.

Discovery of new populations: In addition to the 11 translocated populations, the 2007 status review identified eight new populations discovered since 1998 outside the original range (Figure 3). These new populations are unlikely to be associated with the translocations; rather, they are most likely a result of expansion or discovery of additional natural populations. The populations described in the 2007 review are:

- Northeastern Dorchester County
- Southeastern Caroline County
- Tuckahoe River corridor
- Northern Queen Anne's County (Chino Farms)
- Centreville area of Queen Anne's County
- Kings Creek area of Talbot County
- Northern Somerset County, Maryland
- Nanticoke WMA in Sussex County, Delaware

Since 2007, additional DFS sites have been discovered between some of these eight populations, with several populations within the **estimated dispersal distance** of 2.25 mi of another population. For example, the Nanticoke population is now connected to the large Dorchester County population, which significantly reduces the extinction risk of the smaller Delaware population. Similarly, the Tuckahoe River corridor subpopulation is now connected to the Centreville population. This connectivity greatly improves the survival prospects for both populations.

Acres of occupied forest[2]: When a DFS is detected within or along the edge of a forest tract, that woodlot is considered to be DFS-occupied. The occupied forest is delineated as the forest area contiguous to the sighting and ending at forest breaks provided by named roads or fields. Evidence that a forest block is occupied can come from various sources. Sighting reports provided by a network of knowledgeable Federal, State, and private biologists as well as private citizens record the location, date, and details of a DFS observation and are provided to the CBFO and entered into the GIS database. DFS trapping is typically used to determine if the species is

[2] Note that this review uses the term "occupied forest," while the 2007 status review used the term "occupied habitat." We now consider occupied forest to be a more accurate term, because forest tracts can include areas of both mature forest and young regenerating stands. Although DFS may use young forest for foraging or travel, mature forest provides the full set of habitat features needed for DFS reproduction and survival.

present on a site that may be developed, but it is also conducted on several long-term monitoring sites, including translocation sites, NWRs, benchmark sites, and some State lands. Camera studies, which use a series of remotely triggered cameras to determine if DFS occur on a site, are now used more often than trapping to determine if DFS occur on a potential development site and are also used to amplify our understanding of DFS distribution. These techniques are also used in research studies.

Camera and trapping surveys are also used to determine DFS absence on a site. Using a Service recommended protocol (USFWS 2010), completion of two surveys (one in spring and one in fall) that do not detect or capture DFS is considered to be evidence that DFS are not likely to occur on a site and that take of DFS is not likely to occur from any habitat disturbance. Camera and trapping surveys can also provide some indication of relative abundance, and the potential use of camera surveys to further assess relative abundance is currently under consideration.

2.3.1.1.3 Changes in DFS occupancy of forests

The known range of the species over time has been understood through changes in DFS occupancy of woodlots. When comparing DFS presence or absence in a woodlot at two points in time, trends in occupancy are indicated in four basic ways. *Persistence* (+,+) is indicated when the species is present in both the first and second survey. *Extirpation* (+,0) is indicated when it is present in the first survey but absent in the second. *Colonization* (0,+) is indicated when the DFS is absent in first survey but present in the second. *Discovery* is indicated when the species was present but unknown to us in the first survey, then discovered in the second survey (?,+). In addition, there are sites where the species continues to be absent (0,0) from both surveys.

Absence in any one survey may mean the animal was truly absent, or it may mean the animal was present but not detected. Recent work has focused on improving means of explicitly dealing with the uncertainties surrounding absence information through patch occupancy modeling (MacKenzie et al. 2006). Dealing with these uncertainties is especially important when modeling habitat variables that are associated with a sample of these patches (Moore and Swihart 2005), because erroneous conclusions from the negative habitat associations could otherwise result.

How does uncertainty of absence information affect our understanding of DFS range changes? We are most interested in persistence (+,+) or extirpation (+,-) within the range, and if DFS are detected in both the early and later time periods, we know they are persisting, and there is no bias because there is no absence information. If we do not detect them in the later surveys and assume they are extirpated, they may actually be present in very low numbers and extirpations could be overstated, resulting in conservative estimates of overall population changes. Determining if a new discovery is actually a colonization (0,+) or a discovery (?,+) is not likely to be definitive; that is, we will generally not be able to identify whether the occupied sites discovered in a second time period are due to true colonization or merely a failure to detect DFS during the first survey. However, it is not critical for purposes of this review to make this distinction, because the result in either case is a larger known range and lower extinction risk for the species.

Comparison of occupancy between 1971 and 2001: Reported DFS occupancy of land tracts was first used to monitor the DFS in 1971. Taylor and Flyger (1974) interviewed knowledgeable individuals (e.g., biologists, game wardens, foresters, and landowners) regarding locations where DFS were known to occur and where they were known to be absent (based on none being observed despite frequent site visits). These interviews resulted in documentation of DFS presence at 65 locations and absence at 36 locations on the Eastern Shore. In 2001, Therres and Willey (2005) revisited all 101 locations to assess current occupancy and habitat suitability. Using the same method of interviewing knowledgeable individuals, they determined that DFS persisted at 60 of the 65 sites (92 percent), was extirpated from five sites, and had colonized 11 sites. DFS were therefore considered to be stable to slightly increasing rangewide.

Comparison of occupancy between 1990 and 2010: In 1990, DFS were recorded as occupying 275 Maryland forest tracts totalling 103,125 ac (see Chart 1). Since 1998, we have been recording observations of squirrels and conducting trap and camera surveys. If DFS have been observed in or within 0.28 mi (i.e., the diameter of an average home range) of the woods, they are considered to be persisting in the woodlot. There is evidence of persistence in 181 of the 275 occupied forest tracts identified in 1990, totalling 94,221 ac (see Chart 1). This indicates persistence in 66 percent of the originally occupied woodlots and 91 percent of the originally occupied acreage (because woodlots range in size, the acreage of occupied forest is considered to be a better parameter for comparison than the number of woodlots).

Monitoring of some tracts has led to the conclusion that DFS have been extirpated from occupied forest in three areas: Grasonville, Hog Island, and Eastern Neck NWR (Figure 4). The Grasonville area is an isolated peninsula bounded by water on two sides and the Grasonville community and Route 50 to the north. Apparently, this area had very few DFS in 1990 (G. Therres pers. comm. 2005) and this small population appears to have become extirpated; there is a large block of suitable habitat present, but the isolated location restricts migration into this area. The habitat at the Hog Island site, which had a few squirrels in a very small woodlot, is no longer suitable. The DFS at Eastern Neck NWR, introduced by a hunt club during the 1920s, flourished for many years. In the late 1960s, 22 DFS were moved from Eastern Neck to Chincoteague NWR to start that translocation. Whether too many squirrels were removed or due to other factors, DFS numbers at Eastern Neck have declined for some time. Eastern Neck is a small island with about 500 ac of forest, and this may not have been large enough to support such an isolated population. Although it is possible that DFS could have moved off the island at low tide, we are not currently aware of any DFS nearby.

We are uncertain about the status of 7,671 ac (87 woodlots) of previously occupied forest, where we have neither any recent sightings nor any evidence of extirpation. Some of these areas are likely to be occupied; they are adjacent to other occupied forest tracts but away from most roads and not frequently visited by observers. Nonetheless, even if we assume that DFS are not present at any of these sites, 91 percent of the total acres of forest considered occupied in 1990 are still occupied 20 years later.

Since 1990, we have also found another 32,227 ac to be occupied by DFS (see Chart 1). An average of 1,887 ac of new occupied forest has been discovered each year since 2000 (see Figure 4). Some of these new discoveries are likely to be DFS that have always occurred in low numbers but were undetected, but some may represent true expansion of the DFS population. For instance, there are several locations where landowners, living at a site for 25 years or more, now report DFS and indicate they have seen them only in the last 10 years (see Figure 4). At one site in Caroline County, after two seasons of negative trapping data in 2004, DFS were then observed on the property 5 years later; this is the best evidence of true colonization. The new population discovered on the Nanticoke WMA is also likely to be from colonization, given that State biologists have been working at this site for many years. In Maryland, Delaware, and Virginia, there is a total of 134,778 ac of occupied forest that is currently persisting, newly discovered, or awaiting confirmation of occupancy.

In addition, there have been some sightings of DFS that suggest DFS may be dispersing and exploring areas at some distance from most of the known occupied habitat. In the Pocomoke River corridor of Worcester County, a squirrel has been seen by three individuals on different occasions, but attempts to trap or photo-monitor DFS there have been unsuccessful. This location has been recorded as occupied forest (see Figure 4) but will not be included as part of the DFS range until more information suggests long-term use of the area. A DFS has also been sighted in south-central Sussex County Delaware, but followup photo-monitoring has not detected any more individuals. These sightings could be observations of dispersing DFS.

Summary of range changes: DFS distribution at the time of listing included four Maryland counties, whereas its current distribution includes ten counties (Chart 2). This expansion is the result of 11 successful translocations as well as discovery of new populations outside the area considered to be the species' range at the time of listing and recovery planning. The total area of occupied forest is now 134,778 ac, which is approximately a five percent increase since the 2007 status review. The total range of the DFS now covers 28 percent of the Delmarva Peninsula.

Chart 2. Summary of changes in DFS range.

Summary of Changes in Range	**At time of listing circa 1970**	**As described in recovery plan circa 1990**	**As described in 2007 status review (2005 data)**	**Current status review (2010 data)**
Number of Counties Occupied	**4**	**10**	**10**	**10**
Total acres of Occupied Forest	Not Available	**103,311**	**128,434**	**134,778**
Percentage of Range Occupied	**10%**	NA	**27%**	**28%**

Discovery of new populations has occurred every year since 1998. Though the reporting of sightings can vary with the extent of the outreach and education regarding DFS sightings, we still anticipate continued new sightings occurring every year, as in the past. Over the last 10 years, the average acres of occupied forest discovered is 1,887 ac per year. While the acres discovered could decline somewhat in the future, it seems reasonable to consider that some discovery, even if more limited, will likely occur in the future as it has in the past.

2.3.1.1.4 Population viability analysis for DFS subpopulations

As described in USFWS (2007), a population viability analysis (PVA) model has been developed for the DFS (Hilderbrand *et al.* 2007). This PVA uses demographic features of natural populations to model the extinction probabilities of populations of different sizes, with environmental variability affecting the model parameters described below. The PVA provides a useful tool to assist in understanding the demographic sustainability of the overall DFS population (Sanderson 2006).

Model parameters: Model parameters include fecundity and survivorship. Fecundity, the number of young produced per female, was estimated very conservatively as 1.2 for first-year females and 1.5 for ages two and up based on litter sizes reported in the literature for this species (e.g., 2.4, Lustig and Flyger 1975; 1.7, Larson 1990; 2.2, Dueser 1999). Survivorship was estimated at 50 percent for juveniles (age class 0 to 1 year) and 66 percent for adults, based on Conner (2001). Conner (2001) found adult female survival in an unexploited population of southeastern fox squirrels (*Sciurus niger niger*) in Georgia to be 66 percent (range 55 to 80 percent). Paglione's (1996) estimate of female DFS annual survival (57 percent, range 51 to 63 percent) pooled juveniles and adults, consequently underestimating adult survival. Her results are, however, comparable to Conner (2001).

Fecundity and survivorship values were presumed to vary, and the PVA's model thus incorporated variation of $\pm$20 percent in these parameters. The possibility of having two or more bad years in a row was also accounted for by allowing the correlation between annual survival rates to be as high as 0.4. Using these model features, 1,000 simulations were run as a means of measuring the extinction rates of populations of different sizes.

Minimum viable population size: The population size that is associated with a specific extinction risk can be referred to as a minimum viable population (MVP) (Shaffer 1981). In general, isolated populations of fewer animals have a higher extinction risk simply from their small size and likely environmental variability. For our modeling purposes, we defined a minimally viable DFS population as having at least a 95 percent probability of surviving for 100 years. Using population size and environmental variability associated with survivorship and fecundity, the PVA determined that a population with 65 females, or 130 total animals, met the survival probability threshold. The habitat area required to support a population of 130 DFS, using an average density of 0.3 DFS per ac, is 435 ac. The PVA did not address specific threats that may cause habitat loss on the landscape or other factors that may threaten the species or its habitat.[3]

Criticisms of MVP in the literature have sometimes conflated MVP with recovery goals (Traill *et al.* 2010, Reed *et al.* 2003). There may be situations where the MVP is an appropriate conservation goal for certain species in specific locales (e.g., Suchy *et al.* 1985); however, in most cases, recovery goals are going to consider more than simply the minimum population size

[3] That analysis is precisely what this status review is intended to accomplish; that is, its purpose is to consider the overall security of the rangewide population given all that we know about present and foreseeable threats.

needed to avoid extinction from stochastic events. In this case, the MVP is clearly *not* a recovery goal, as it does not describe the number of populations and their distribution that is needed to avoid extinction after taking all threats into account. Nonetheless, MVP is a useful tool for gauging extinction probabilities of the DFS rangewide, because it allows us to gauge the extinction risk of subsets of the population and then consider the demographic sustainability of the overall DFS population (Sanderson 2006).

Using dispersal parameters and existing data on DFS movements, Hilderbrand *et al.* (2007) estimated that 75 percent of a given DFS population would have the ability to disperse to areas within 2.25 mi (see Appendix A). Thus, DFS in forest areas that are within 2.25 mi of each other and not separated by physical barriers such as rivers, cities, and constricted peninsulas were considered likely to be interbreeding. We defined these interbreeding groups of DFS as **subpopulations** and used the PVA to evaluate the potential extinction risk of these subpopulations.

As mentioned above, 435 ac of suitable habitat are required to support a population of 130 DFS. If we assume that all forest area is approximately 50 percent mature (and thus suitable breeding habitat) and 50 percent young regenerating stands, then a sustainable population of 130 DFS can be maintained in areas with about 800 ac of forest. Our current range estimate of 134,778 ac of occupied forest thus theoretically supports about 168 MVPs, and based solely on this we could conclude that the entire rangewide population is large enough to be secure. However, the DSF distribution is not entirely connected, necessitating an assessment of the vulnerability of the smaller subpopulations.

Using the PVA to assess extinction risk of subpopulations: We identified 22 subpopulations, each comprising a cluster of occupied habitats within 2.25 mi of each other and each more than 2.25 mi or otherwise separated from other such clusters (Figure 5). The relative risk of extirpation of each subpopulation is based on its size (total acres of occupied forest) and relative isolation from other groups.

The largest subpopulation, Dorchester/Nanticoke, contains 95,725 ac of DFS occupied forest. This subpopulation is now known to be larger than described in the 2007 review and is connected to the Nanticoke population in Sussex County, Delaware. The next three largest subpopulations are southern Talbot, Tunis/Wye Mills, and Tuckahoe River corridor. These are also larger than described in the previous review and are barely separated based on the 2.25 mile distance; it is highly likely that there are some DFS-occupied patches in the short distances that separate these three subpopulations. Further, these large subpopulations have additional available habitat that could be colonized, and they are thus likely to continue to increase in size. All four of these subpopulations have at least three times the habitat required to support a minimum viable population and, at their current size, are thus considered secure from extirpation. Nine other subpopulations contain at least 800 ac of occupied forest and have room to expand; these subpopulations are also considered to be secure from extirpation.

Seven smaller subpopulations are currently isolated by distance or rivers, posing a moderate risk of extirpation, and two very small populations that are isolated by water and roads and development (Route 301/Route 50 split and Hampton Woods) have a high risk of extirpation.

However, even with these losses, the majority (98 percent) of DFS-occupied forest is in patches of at least 800 ac and is considered to support a demographically secure subpopulation.

In the following sections, we describe the mature forest habitat available near and between these 22 subpopulations and overall forest connectivity.

Estimated total population size: Using a total of 134,778 ac of occupied forest and DFS density estimates, we can estimate approximate rangewide population size for DFS. Although density estimates are difficult to make for nonterritorial animals, we have density data from mark-recapture studies at Blackwater and Chincoteague NWRs (Paglione 1996, Pednault-Willet 2002). Both studies had sites with densities that ranged from a low of 0.15 DFS per ac to a high of 0.5 DFS per ac (Paglione 1996, Pednault-Willet 2002) for an average of 0.33 DFS per ac. In the 2007 review, we estimated a population size of 19,265 DFS using the low density estimate (0.15 DFS per ac), but this figure was based on a definition of occupied habitat that included both young and old forest.

New information since the last review provides a somewhat improved estimate. The area of occupied *mature* forest can now be identified using LiDAR data (described in more detail in a later section). We also know that DFS density varies across the landscape. Using trapping catch-per-unit effort, frequency of camera detections, observations, and general knowledge, densities of DFS in Dorchester and Talbot Counties are considered to be within the average to high range, while densities of DFS in Queen Anne's County and the periphery of the range are probably average to low. For example, using trapping data from five sites in Talbot and Dorchester Counties where woodlots were fairly distinct (generally bounded by fields or marsh on three sides), we can divide the total number of unique individual DFS captured by the acreage in the woodlot, resulting in coarse density values of 0.25, 0.16, 0.09, 0.25 and 0.08 DFS per ac (average of 0.17 DFS per ac). These values are clearly underestimates, as not all of the individuals in a woodlot are captured in any trapping event; for example, mark-recapture population estimates at Chincoteague NWR are more than twice the number of individual animals actually caught (USFWS 2010); using this approach, we could assume the actual value of the coarse estimate of 0.17 DFS per ac to be about 0.33 DFS per ac. Paglione (1996) also trapped and radio-collared ten DFS in a 9-ha woodlot bounded on three sides by fields, corresponding to a density of 0.45. Mark-recapture estimates of the number of DFS in the Egypt tract benchmark site have varied over the years, with a corresponding density estimate ranging from 0.5 DFS per ac in the 1990s (Paglione 1996) to 0.36 DFS per ac using the most recent 13 years of data (Gould 2009). Given a range of values in these areas that spans from 0.08 to 0.5 DFS per ac, and knowing that sites can vary over time, we consider 0.33 DFS per ac to be a reasonable estimate for Talbot and Dorchester densities.

Taking into account only the occupied mature forest for Maryland identified by LiDAR, and assuming (because of observations) that the occupied forest is mature in the Delaware and Virginia sites where the DFS occurs, we calculated a total of 77,081 ac of DFS-occupied mature forest. Further, using an average density estimate for Dorchester and Talbot Counties of 0.33 DFS per ac and the low density estimate of 0.15 DFS per ac everywhere else, our best estimate of the rangewide population size is 22,368 DFS, or, more roughly, 20,000 animals. While this is similar to the 2007 estimate despite increases in the occupied forest, it is considered to be a more reliable estimate because of its focus on mature forest. For the sake of contrast, using only the low density estimate of 0.15 DFS per ac over 77,081 ac of mature forest, the total population size is calculated to be 11,562 DFS, and if a more moderate density value, such as 0.24 DFS per ac, for Dorchester and Talbot Counties is used, the total is 17,000 animals. These are very conservative estimates, and we think the data support higher estimates of approximately 17,000 to 20,000 DFS.

Several authors have offered rules-of-thumb on how many animals are necessary for sustainable populations. Reed *et al*. (2003) estimated that a population size of about 7,000 was necessary, and Sanderson (2006) generally described it in the thousands. Even our lowest estimates of total number of DFS exceed these. However, we agree with Thomas (1990) that the best assessments include empirical consideration of how the population is responding to the threats on the landscape. We consider the occupancy assessment of persistence versus extirpation in woodlots over the last 20 years (see Chart 1) to provide the best indication of DFS population sustainability, because it describes the status of populations facing the actual threats that occurred on the Delmarva Peninsula over the past 20 years. Further assessment of threats and DFS response is provided in section 2.3.2 of this review.

2.3.1.2 Distribution and abundance of DFS habitat

Before we can evaluate the potential threats to the DFS and its habitat, we need to understand the abundance and distribution of that habitat on the landscape. Is there sufficient available habitat for the DFS to persist? Is habitat connectivity sufficient to allow for expansion? The following provides an overview of DFS habitat on the Delmarva Peninsula.

2.3.1.2.1 Land uses on the Delmarva Peninsula: The Delmarva Peninsula is primarily a rural landscape where agriculture and forest lands are the predominant land cover. The counties in the range of the DFS are approximately 47 percent agriculture, 36 percent forest, 9 percent wetlands and 7 percent developed (Figure 6, Table 2). The northern four Maryland counties (Kent, Queen Anne's, Talbot, and Caroline) are predominantly agricultural land with about 30 percent of the area forested; the southern four Maryland counties (Dorchester, Somerset, Wicomico, and Worcester) have about 40 percent of the land area in forest. The southern counties also have extensive coastal wetlands. The largest cities in the Maryland counties are Salisbury and Ocean City, both of which are outside the DFS's range. The largest cities within DFS range are Easton and Cambridge. In Sussex County, the city of Seaford is at the edge of the range; larger cities in Delaware occur well to the north of DFS range.

The Delmarva Peninsula is primarily privately owned land. In the eight Maryland counties and Sussex County in Delaware, 10 percent of the land is in Federal or State ownership (Figure 7, Table 3, Appendix C). While most land is privately owned, there is extensive acreage in conservation easements that protect land from future development. Conservation easements are pursued through a variety of Federal, State, and private programs (e.g., State programs such as the Maryland Program Open Space and Maryland Environmental Trust and Federal programs such as the Wetland Reserve Program). Together, these programs protect 12 percent of the private land in the counties in Maryland and Delaware with DFS habitat. The Maryland and Delaware conservation programs are further discussed in section 2.3.2.1.1 and Appendix D. The DFS population in Virginia is wholly conserved within the Chincoteague NWR on the island of Assateague.

The nine Maryland and Delaware counties where DFS occur contain almost 900,000 ac of forest (see Table 2). Forests in the DFS range tend to be dominated by hardwoods in the northern counties and by pines in the southern counties, but mixed hardwood/pine forests occur throughout the DFS range. Timber has been harvested on the Delmarva Peninsula since its European settlement in the 1600s, with the most active timber harvest occurring on the lower shore where large tracts of forest are dominated by pine. Forested areas throughout the peninsula are a mosaic of mature forest and young regenerating stands; although DFS use mature forests as breeding habitat, they will forage or travel through stands of all ages.

2.3.1.2.2 DFS habitat models: As previously mentioned, DFS habitat consists of mature forest of mixed pines and hardwoods with a somewhat open understory. Mature forest with large trees provides greater food and more den sites for DFS. Both an original and revised habitat model (Dueser *et al.* 1988, Dueser 2000) found DFS to be more likely to occur in stands of mature forests with a greater proportion of trees greater than 12 in dbh (diameter at breast height) and higher canopy closure. A more open understory was also a good predictor of DFS presence. The proportions of pines and hardwoods preferred by DFS have varied in the models, primarily because of where the data used to build the model came from (southern or northern shore). This primarily reflects the broad range of forest types used by DFS from mostly hardwoods to mostly pines. Further, DFS occur in stands that range from upland to wetland forests, and no particular habitat preferences among these are evident (USFWS 1993).

The DFS is preference for mature forests is further supported by a study of DFS presence/absence using photo-monitors at the Chesapeake Marshlands NWR Complex in Dorchester County (Morris 2006). DFS were more likely to be "caught" on camera where the surrounding habitat has the greatest canopy cover, and greatest number of large trees and tall trees. Thus, features of mature forest can predict stand-level DFS occupancy (Dueser 2000) as well as forest areas within the stand that are more likely to be occupied (Morris 2006).

2.3.1.2.3 Using LiDAR to inventory DFS habitat: Until recently, the Service was unable to inventory the acres of forest habitat available for DFS, because remote sensing data generally distinguish forest types by the dominant tree species (e.g., pines and hardwoods) rather than by the important habitat variables of forest maturity. For instance, the analysis could delineate areas of pine but not whether they were 10-year-old regenerating stands or 60-year-old mature stands. However, mature forests can be differentiated from younger stands by the height of the forest canopy. Tree height is, likewise, a predictor of which patches of forest are most likely used by DFS (Morris 2006).

It is now possible to measure forest canopy height using Airborn LiDAR laser data. LiDAR data are collected by aircraft and can measure both canopy and ground elevation; the difference between the two then provides the forest height. In Delaware, Nelson *et al.* (2005) found that transects of forest canopy height measured by LiDAR were correlated to DFS habitat identified by the Dueser habitat model (Dueser 2000); that is, 78 percent of the LiDAR transects with average canopy heights greater than 20 m were also considered to be suitable DFS habitat according to the Dueser (2000) habitat model applied to these same transects.

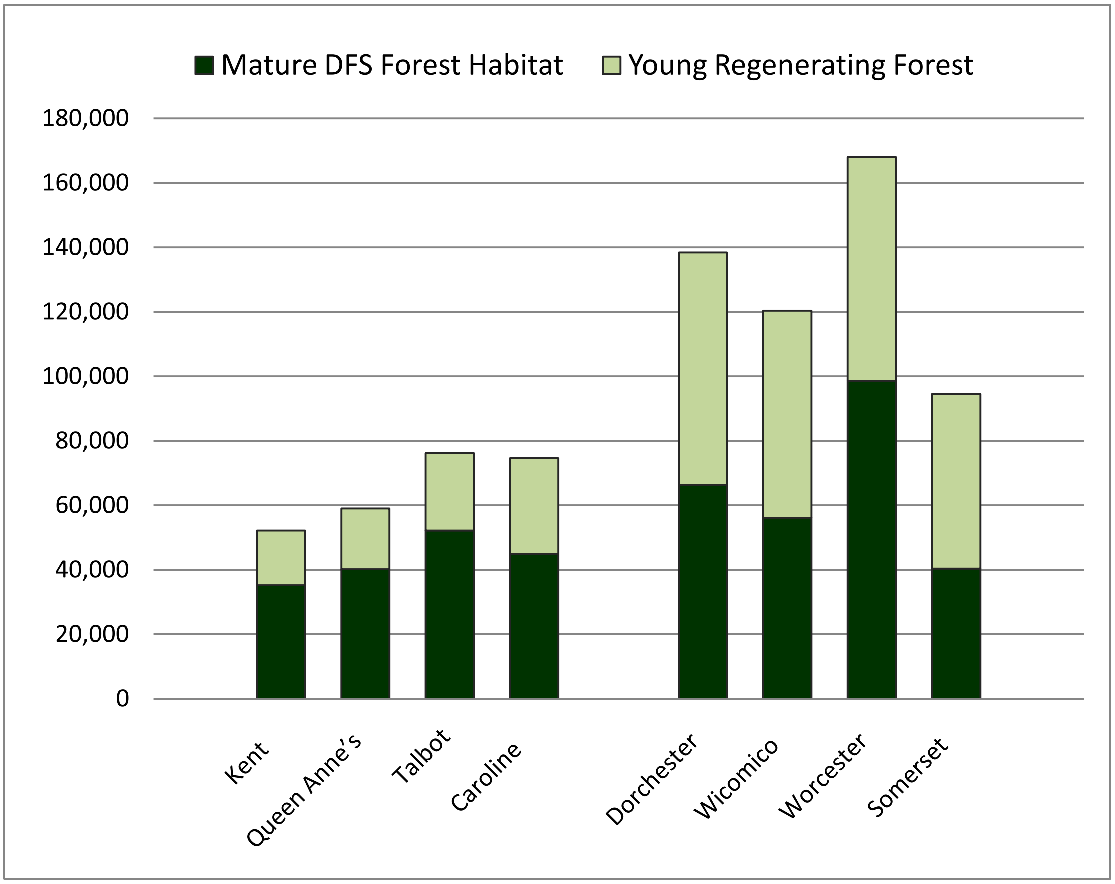
Based on these results, the Service initiated an analysis of Maryland LiDAR data, which resulted in a map of tall, mature forest most likely to be suitable for DFS (Appendix E). This model was then tested using the camera point locations in Dorchester County studied by Morris (2006). Camera sites where DFS were detected using cameras had significantly more LiDAR-defined mature forest than did camera sites where DFS were not detected (see Appendix E). Although further testing is desirable, the analysis indicates that the LiDAR model of mature forest is reflective of likely DFS use; at the very least, it discriminates between mature forest that is potentially suitable for DFS and younger stands that are not. This is not to suggest that the LiDAR model is a perfect predictor of DFS use or that all LiDAR-defined mature forest constitutes suitable habitat, as there are other features not measured by LiDAR that can influence DFS use. Nonetheless, LiDAR data can help us identify areas of mature forest, and we know that tree height, canopy closure, and tree size are predictive of DFS use (Dueser1988, Dueser 2000, Nelson *et al.* 2005, Morris 2006).

The LiDAR mapping has identified over 430,000 ac of mature forest in the Maryland portion of the species' current range[4] (Table 4, Chart 3), which amounts to 43 percent to 68 percent of the forest areas in the eight Maryland counties. Although the percentage of mature forest is higher in the northern four counties, there are more acres of mature forest available in the southern four counties. Recognizing that occupied habitat consists of both mature and regenerating stands, analysis of the mature forest component shows us that the percentage of the total available mature forest currently occupied by DFS ranges from 1 percent to 68 percent in the four southern Maryland counties (see Table 4). In other words, even in Dorchester County, where DFS are most abundant, 32 percent of the mature forest is unoccupied and can provide additional habitat for DFS to colonize. In the remaining counties, where DFS occupy up to 28 percent of the mature forest, there is ample unoccupied mature forest to enable further expansion of the DFS rangewide population.

This mature forest is also broadly distributed throughout the range (Figure 8). Mature forest stands are often found in riparian corridors, probably because these areas proved too wet to farm or log; these forested corridors can provide habitat for expanding populations of DFS, as seen in the Tuckahoe River corridor. However, there are also large tracts of mature forest distributed in upland areas throughout the range. Furthermore, observations of DFS indicate that individual animals can move through young forest, clearcuts, and agricultural fields to get to suitable habitat, strongly suggesting that the potential for expansion is good.

[4] Comprehensive LiDAR data are not yet available for Delaware or Virginia.

Chart 3. Acres of mature forest suitable for DFS, by county, using the LiDAR model.



2.3.1.2.4 Connectivity of the forest habitat: Forest habitat connectivity is indicated both by LiDAR maps of mature forest and by an analysis of total forest connectivity on the Delmarva Peninsula. With regard to the latter, Lookingbill *et al.* (2010) conducted a GIS analysis of the connectivity of forest patches on the Peninsula. This Peninsula-wide study could not rely on the LiDAR model, which was limited to the Maryland counties, so it looked at all forest as identified by satellite data and evaluated the connectivity of 400-ha (175-ac) forest patches, a patch size applicable for DFS. Although the DFS is not a forest interior species and does not actually require forest blocks this large, the Lookingbill *et al.* (2010) model does provide a useful analysis of forest connectivity between forest blocks that could hold larger populations. Using a modeling routine called "J-walk" to assess the likelihood of a DFS crossing the landscape between forest patches based on intervening habitat types (e.g., forest is ranked easiest to travel through, agricultural fields are possible, and large rivers are impossible), the model identifies the 175-ha forest patches that a DFS could move among. This network of connected blocks of forest is illustrated in Figure 9, in which the length of the lines illustrates the distance within which the 175-ha forest blocks are connected and across which a hypothetical DFS could successfully "walk" (the actual path would not follow a straight line).

The long radial lines in the southern Maryland counties indicate high patch connectivity before the hypothetical DFS must stop (generally at the edge of the coastal marsh). This suggests that there are few obstacles to DFS dispersal throughout this southern area. The model underscores the connectivity of the larger forested areas in the southern counties, indicating that there is ample connected habitat for expansion of both natural and translocated populations in the southern portion of the squirrel's range.

The J-walk model assumes the Choptank and Tuckahoe rivers to be barriers. This appears to be a reasonable assumption for the wider Choptank River but may not be accurate for the upper Tuckahoe River (see Figure 9). The DFS is found on both sides of the Tuckahoe River, and crossing at narrower reaches of the river, especially in the winter when rivers are frozen, is probably more likely than the model suggests.

In addition to analyzing connectivity between forest patches, the model is useful for examining potential forest pathways that could connect DFS subpopulations (Figure 10). The large Dorchester County DFS population has two main forested corridors extending to the northeast. The DFS has already expanded into the Nanticoke area of Delaware using the southern of these two routes, and the potential exists to expand into Caroline County along the more northerly corridor, which is well protected by State ownership. It is worth noting that although the model highlighted these two forested paths out of Dorchester County, DFS also occur throughout the more fragmented forests along the Choptank River and into Caroline County; these forest fragments do not reach 175 ha in size. Further, the DFS is not a forest interior specialist; it frequently uses forest/agricultural edges and riparian corridors along with smaller blocks of forest for travel. This suggests that the model is overly conservative and that DFS do not require the large tracts of forest used by the model.

The J-walk model indicates that, in addition to the Dorchester County subpopulation, the southern Talbot and Tunis/Wye Mills subpopulations are linked by two forest pathways (see Figure 10); these subpopulations are almost near enough to be considered one large subpopulation. Within the next 5 years, we are likely to have evidence (e.g., additional known occurrences between the two subpopulations) showing that DFS in each of these two subpopulations are within dispersal distance of the other.

In summary, the availability of unoccupied mature forest, especially in the vicinity of currently occupied habitat, suggests that there is suitable habitat that DFS can move into. The expansion of the DFS range since listing, new information on DFS movements, and an abundance of mature forest suggest that available habitat is not a limiting factor for population growth. The connectivity of forest tracts across the Delmarva Peninsula also appears to be sufficient to allow further expansion.

2.3.2 Five-factor analysis of threats

The DFS was listed as an endangered species in 1967 because the population was considered to have declined to 10 percent of its historical range. The most likely causes for this decline were described as loss of mature forest from clearing land for agriculture, short rotation timber harvest, and overhunting. The 1993 recovery plan (USFWS 1993) emphasizes habitat changes as a main reason for its decline; however, the DFS Recovery Team has subsequently speculated that overhunting, especially in the 1950s and 1960s, may have been a strong contributing factor.

Squirrel hunting was far more popular at that time, and because of their larger size, DFS may have been preferred to gray squirrels by hunters.

For purposes of this review, these and other identified threats to the long-term survival of DFS have been categorized into the five factors used to list species under the ESA; that is, habitat changes, overutilization, disease or predation, inadequacy of regulatory mechanisms, and other factors. These listing factors, including the extent to which conservation actions have offset specific threats to the species, were previously assessed in the 2007 status review (USFWS 2007), which concluded that the threats to this species did not endanger it with extinction and that it should therefore be classified as threatened. In this status review, we are re-evaluating these factors in light of information obtained since 2007.

It should be noted that in trying to predict trends through the "foreseeable future," we have examined past trends (i.e., over the past 20 to 40 years) as a basis for making informed projections over a similar future time frame. Predictions always have some uncertainty, but the farther we try to look into the future, the greater the uncertainty; a time frame of 20 to 40 years allows for more reliable use of available data to inform our projections, particularly when we can look at past DFS responses to threats over an analogous time period. We should also note, however, that it is not necessary to assign identical time frames to all threats. For instance, although rates of sea level rise can be scaled to any time frame, they are typically described in longer time frames because effects would likely be minor or not detectable in a shorter period. Overall, our general approach to analyzing each of the five factors is to first summarize past trends in the threat and the observed DFS response to that threat, and follow this with predicted future trends.

2.3.2.1 Factor A. Present or threatened destruction, modification or curtailment of the species' habitat or range

The 1993 recovery plan stated that, "timber harvest, short-rotation pine forestry, and forest conversion to agriculture and/or structural development (housing, roads, industry) constitute broad threats to the Delmarva fox squirrels and their habitat" (USFWS 1993). The 2007 review concluded that the only potential extinction risk to DFS was a possible loss of mature forest in some areas of the landscape, with the possibility of continuing losses. It is important to note, however, that this conclusion acknowledged that sufficient data were lacking and called for further investigation. The LiDAR analysis summarized above enables a more definitive assessment of current and projected habitat availability.

As mentioned in section 2.3.1.2.1 of this review, the Delmarva Peninsula – bounded by the Chesapeake Bay on the west and the Atlantic Ocean on the east – is characterized by a rural landscape dominated by agricultural land and forests. Few large cities or industrial areas fall within the current range of the DFS. The Factor A analysis focuses on the habitat-related effects of residential development, sea level rise, and timber harvest.

2.3.2.1.1 Threat of habitat loss due to forest conversion for development

Effects of residential developments: Unlike the gray squirrel, the DFS does not inhabit residential developments; that is, it is not a suburban animal. The DFS does occur near homes in forested areas with low-density housing (e.g., where a home may be surrounded by 40 ac of woods) and will visit the yards of farm houses to access hickory or pecan trees. We know, however, that they do not inhabit large suburban developments, although the precise density of housing that can be tolerated by DFS is unclear. We have conducted repeated trapping at one site with 16 homes, from pre-development to build-out, on a somewhat isolated peninsula (trapping data are on file in the CBFO). From this we have inferred that on isolated sites where access to large blocks of habitat is limited, small (e.g., 25-ac) woodlots near housing developments may not be able to support DFS over the long term. We are currently following DFS use of small blocks of woods before and after construction of homes in adjacent fields to better understand the long-term effects of housing in different landscape settings. Currently, DFS are continuing to use most of these wooded areas but it remains to be seen how long this use continues or what landscape settings will enable continued use.

Residential development can negatively affect DFS through direct loss of forest habitat, degradation of habitat near homes or roads (the extent of these effects are still being investigated), and potential isolation of populations if developments are constructed in areas needed for dispersal. If a dense residential development is built in a forested area, we do not consider DFS likely to inhabit the area after construction.

With regard to development patterns, most residential housing projects constructed on the Eastern Shore of Maryland in the past 5 years were not constructed in forested areas but built in agricultural fields. Agricultural fields are being targeted for development because most of the remaining woods are on wet soils. Wetland protection laws and the need for soils suitable for septic fields prevent much of the forested area from development. The Maryland Forest Conservation Act and Critical Area Laws also help prevent development in forested lands.

The effects on DFS occupying woodlands adjacent to agricultural lands that have been converted to residential developments include the loss of agricultural food sources and possible habitat degradation caused by disturbance emanating from home sites (e.g., incursions by dogs and cats). Housing developments in farm fields not in close proximity to woodlands are considered to have little impact on DFS. Thus, the effects of residential developments on local DFS populations range from major to negligible depending on how many acres of forest are lost and to what degree homes are built near occupied forest.

Past development trends: The Delmarva Peninsula is basically a rural landscape, but the human population has increased. For instance, in the eight Maryland counties where DFS occur, the human population increased from about 200,000 to 300,000 from 1970 to 2000 (http://planning.maryland.gov/msdc/popproj/TOTPOP_PROJ08.pdf). The acres of developed land increased from 3 percent of the landscape in 1973 to 8 percent in 2002 (Maryland Office of Planning 2008). Although data are not yet available, it is virtually certain that acres of developed land have further increased from 2002 to the present time.

During this same time period, a variety of State laws and programs were put in place to counteract the rate of development (see Appendix D). These include the Maryland Forest

Conservation Act, which requires offsetting forest clearing with forest protection or afforestation, and the Maryland Critical Area Law, which now requires that the 200 feet (ft) of land upshore from tidal waters cannot be developed and that the forest in this area must be maintained.[5] As mentioned above, these laws, along with the Clean Water Act and the need for soils that are suitable for septic systems, mean that most Eastern Shore development now occurs on agricultural land.

In addition, several State programs that protect private land from development on a voluntary basis have resulted in conservation of over 240,000 ac of private land (see Table 3). Most of this land is protected by the following programs:

- The Maryland Environmental Trust (MET), initiated in the 1970s, holds voluntary easements (with tax benefits to landowners) on almost 60,000 ac of private lands in the eight-county area. The MET typically co-holds these easements with private land trusts such as the Eastern Shore Land Trust.

- The Maryland Agricultural Land Protection Fund (MALPF), initiated in the 1980s, is designed to protect the best farmland from development. Landowners are compensated for relinquished development rights, and easements are placed on entire farms, including both agricultural and forest lands. The protection of this agricultural land is becoming increasingly important as State and Federal laws that protect forested wetlands push development into agricultural fields. The MALPF currently protects 112,000 ac across the eight Maryland counties.

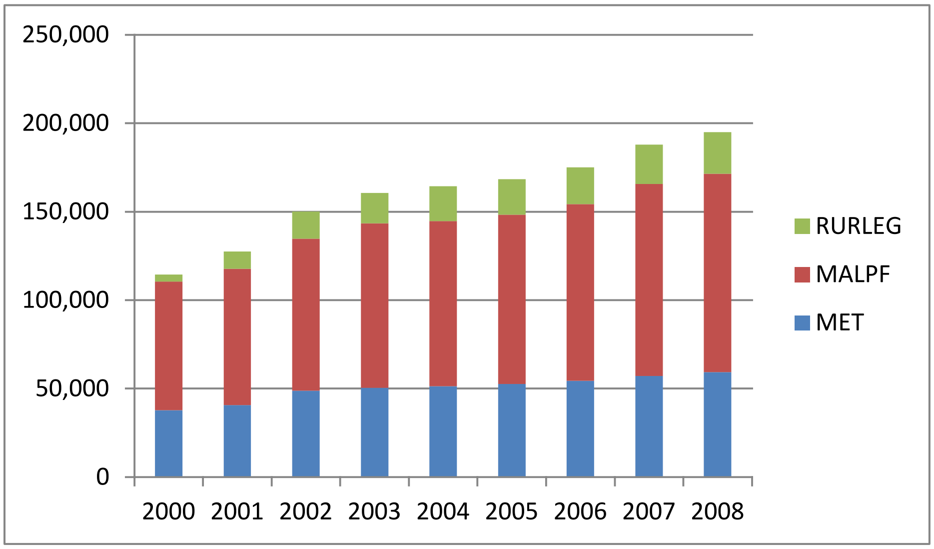
- The Rural Legacy Program began in the 1990s and is specifically designed to offset development anticipated in Smart Growth areas. Each county defines a target area for protection, and then, over time, specific parcels in the target area are protected.

Together, these programs protect 240,828 ac of private land from development in the eight Maryland counties, and the rate of protection compared to development has been impressive; collectively, the three programs have protected 8,956 ac per year from 2000 to 2008 (Chart 4), which is about three times greater than the rate of development from 1973 to 2002 (Maryland Office of Planning 2005).

Overall, approximately 30 percent of DFS-occupied forest across the Delmarva Peninsula, including occupied forests in Delaware and Virginia, is now protected from development (Table 5). This includes approximately 40,000 ac of protected and occupied forest, which is about 45 times the size of the minimum viable population value identified in the PVA (see section 2.3.1.1.4 of this review).

[5] The width of this protected buffer was increased from 100 to 200 ft in 2008 [2008 Md. Laws Ch. 119 MD. CODE ANN., NAT. RES. II § 8-1808.10(b) *et seq.* (also see http://www.dnr.state.md.us/criticalarea/mapupdate.asp)

Chart 4. Cumulative acres of private land protected by the Rural Legacy Program, Maryland Agricultural Land Protection Fund, and Maryland Environmental Trust in eight DFS-occupied Maryland counties.



Projected future development: Population trend data from the report, "A Shore for Tomorrow – A Visioning Series from the Maryland Department of Planning" (Maryland Department of Planning 2008), was used in the compilation of this 5-year review. This report, based on human population census data from 2000, provides the most current comprehensive review and analysis of development trends specific to Maryland's Eastern Shore.[6]

The Maryland Department of Planning (2008) predicts that from 2008 to 2030, the human population will grow from 300,000 to 420,000. Further, under the worst case scenario where Smart Growth policies are not used and sprawl is maximized, the amount of developed land in the 8 Maryland counties could encompass 14 percent of the landscape by 2030. Existing development and the Smart Growth areas where development is expected under the worst case scenario are identified in Figure 11; however, if Smart Growth policies are adhered to, the 2030 estimate is reduced to 11 percent development (Maryland Department of Planning 2008). Although the greatest growth under both scenarios is expected to occur in the vicinity of Salisbury and Ocean City, which are outside the current range of the DFS, sprawl development in Queen Anne's County and the area around Easton would occur within the DFS's range.
We assessed the potential threat of DFS habitat loss from future development by overlaying the acres of existing occupied forest with areas projected to be lost to development, including: (1) Smart Growth areas (excluding the acres that are protected by easement), (2) areas where development projects are already planned, and (3) areas that are projected to be lost by 2030 if Smart Growth policies are not used. Both the projected areas of development and the acres of lost occupied forest were analyzed by the Maryland Planning Department and are illustrated in Figure 11.

[6] Since the publication of "A Shore for Tomorrow," the 2010 census data for Maryland have been issued. Although a detailed examination of these data was not available for preparation of this review, the 2010 data appear to support our projections.

Overall, 3 percent (5,643 ac) of the forest area currently occupied by DFS is anticipated to be lost to development by 2030. This level of loss is relatively small because most of the development on the Delmarva Peninsula is projected for geographic areas where DFS do not occur (e.g., Kent Island, Salisbury, Ocean City). Development could exacerbate problems for DFS subpopulations that are already small and isolated, such as Hampton Woods and the Route 301/Route 50 split. Nonetheless, these losses would not pose any measurable increased extinction risk for the rangewide DFS population.

The discovery of additional occupied forest may offset this projected loss of occupied forest. If past trends continue, discovery of new occupied areas can be expected. In the past 10 years, discovery of new occupied forest has occurred at the rate of 1,887 ac per year. Even if we discover new occupied forest at only half that rate (944 ac per year) in the future, we will have offset the anticipated losses from development in six years. Put another way, by 2030 we will have discovered 18,880 acres of new occupied forest and lost only 5,643 acres to development.

In summary, in the past 40 years, development has eliminated some DFS habitat, but the DFS range has expanded despite these losses. Although past increases in DFS occurrences are attributable in part to the cessation in hunting and DFS translocations, the number and distribution of naturally occupied woodlands have also increased. The discovery of new occupied forest is anticipated to substantially exceed the anticipated losses of forest from future development. Protection of DFS occupied forest from future development has been successfully pursued through several State programs, and a number of State laws are now more protective of DFS forest habitat than was the case in the past. These protections are likely to continue into the future, resulting in protection of additional forest habitat. Given that future losses of occupied forest should be relatively small, combined with the availability of ample unoccupied habitat for DFS to move into, the loss of occupied habitat due to development does not pose an extinction risk for the DFS.

2.3.2.1.2 Threat of habitat loss from sea level rise

To understand the effect of sea level rise on the Delmarva Peninsula, we must consider not only sea level rise but also land subsidence. The two factors combine to result in rates of *relative* sea level rise. The Delmarva Peninsula is a low lying landform, and increases in the relative sea level of the Chesapeake Bay can flood and kill shoreline forests that are habitat for DFSs. Although these dynamic processes have been occurring for centuries, relative sea level rise has increased at an accelerating rate. The DFS is not a coastal species in that it does not depend on coastal habitats specifically, and this moderates its vulnerability to sea level rise compared to other marsh-dependent species. However, it does occur in forest blocks along the edge of the Chesapeake Bay where sea level rise has occurred in the past and will occur in the future.

Sea level rise in the past: The forces of land subsidence and sea level rise have resulted in a long history of island loss and formation in the Chesapeake Bay. Historical islands that housed lodges for Presidents and whole communities of waterman have disappeared into the Chesapeake Bay (Cronin 2005). Sea level rise, land subsidence, and other factors have resulted in accelerated rates of relative sea level rise, especially in the lower portions of the Delmarva Peninsula

(Kearney *et al.*1988, USGS 1998, National Wildlife Federation 2008). Note that relative sea level rise as described in these references includes both the effects of subsidence and actual increases in water levels. The Sea Level Affecting Marshes Model (SLAMM) includes changes that result from inundation, erosion, overwash, and saturation (collectively referred to as sea level rise in this discussion). Historically, these forces combined to produce a relative sea level rise in the Chesapeake Bay region of 3.21 to 3.52 millimeters (mm) per year (0.1263 to 0.1385 in per year), or approximately 1 foot (ft) per 100 years in the Chesapeake Bay region (NOAA 2006).

Loss of some forest stands in southern Dorchester County is already apparent where shoreline timber stands at the lowest elevations have been killed by saltwater from recent hurricanes. Although we cannot precisely quantify how much occupied habitat has been lost in the past 40 years, the LiDAR analysis of forest height and canopy cover has identified at least 170 ac of forest at the edge of coastal marshes that are now standing dead trees.[7]

Future effects of sea level rise and climate change: A recent analysis of sea level rise in the Chesapeake Bay provides several future scenarios using the SLAMM model (National Wildlife Federation 2008). Several future rates were projected in many areas including a mean value of 6.7 inch (i)n by 2050 (40 years), a max value of 11 in by 2050 and a "1 meter" scenario of 16 in by 2050 (based on a rate of 1 meter (m) in 100 years) (National Wildlife Federation 2008, p 16). Projection of 1 m inundation by 2100 for the entire Delmarva Peninsula poses dramatic losses of coastal marshlands and a 5 percent loss of dry land by 2100 (National Wildlife Federation 2008, p 19). This same scenario for low-lying Dorchester County results in a 45 percent loss of dry land in the county by 2100 (National Wildlife Federation 2008, p 63). The SLAMM analysis does not distinguish between various forest types or areas specifically occupied by DFS, thus we conducted a GIS analysis to investigate the effect of sea level rise on DFS occupied forest.

Using our GIS, we calculated the acres of DFS-occupied forest that might be lost due to sea level rise by projecting an inundation level of 24 in on the landscape at year 40. This is four times the rate of the A1B Mean scenario (National Wildlife Federation 2008, which uses a mean sea level rise of 6.6 in in the next 40 years (i.e., by 2050). This rate is also higher than the aforementioned 1 m per 100 years scenario. We thus considered the 24 in inundation scenario to be the very worst case for the next 40 years, although it would be a more likely scenario over a 100-year time frame (National Wildlife Federation 2008). While the SLAMM model was built using raster data at a 30 m x 30 m cell resolution, we were able to obtain LiDAR data for the 24 in per 40-year scenario at a 2 m x 2 m cell size (Towson State University 2006) and combined this higher resolution GIS data layer with the DFS occupied habitat.

Using the 24 in per 40-year inundation scenario, the greatest effects on DFS are seen in the southwestern portion of Dorchester County (Figure 12). The landscape here is a convoluted shoreline bounding a mix of marsh and forest. With 24 inches of inundation, the marsh would be submerged, and peninsulas and forested islands would gradually become smaller; eventually, the forest is likely to be killed by saltwater intrusion. Using the 24 in inundation scenario, 23,060 ac of currently occupied forest would either be lost or restricted to isolated islands. We considered any small pieces of remaining habitat in this area to be lost because of their isolation on islands.

[7] These areas are identifiable using LiDAR because of their tall height but low percentage of canopy cover.

In addition, 14,267 ac of habitat along the remaining southern edge of the county would eventually be destroyed, causing DFS to move inland. Noting that the deterioration of these 14,267 ac of forest on the fringe of the coastal marsh is probably less of a problem because DFS can move into connected habitat, we have nonetheless considered all of these effects as habitat loss.

Given our current understanding of DFS dispersal and population dynamics, the expected DFS response to these changes is that at least some DFS would gradually leave the forested islands and move to more upland areas. The DFS is known to travel across areas of marsh and can move at least 40 to 50 m across marshland between forested islands (L. Miranda pers. comm. 2010). They may also move across frozen marsh in the winter. Despite the DFS's ability to move, some isolation and loss of individuals is likely to occur, and a portion of the squirrel's habitat in southwestern Dorchester County would eventually become unsuitable or disappear. As noted previously, however, currently unoccupied but suitable habitat is available for the DFS; therefore, we do not consider habitat loss due to sea level rise to be a limiting factor.

The 24 in inundation scenario does not play out the same in other parts of the range. In the series of peninsulas in northwest Dorchester County called the "neck region," the 24 in inundation scenario results in shrinkage of available habitat, although it does not create islands, and the DFS have habitat to move into (see Figure 12). This is also the case in other portions of the range near the Chesapeake Bay and the Atlantic Coast. In these areas, currently occupied habitat may be affected by sea level rise, but the area that would be lost is connected to the land, and the gradual loss can be accommodated by shifts in DFS home ranges to adjacent but currently unoccupied habitat.

The most coastal population of DFS is on Chincoteague NWR, a barrier island that could be severely affected by sea level rise (National Wildlife Federation 2008). The refuge's Comprehensive Conservation Plan (CCP) (under development) will address this issue, and the refuge may consider future land acquisitions on the Delmarva Peninsula mainland. Chincoteague will continue to manage for DFS into the future whether or not the species remains listed. In addition, translocations of DFS to areas outside refuge boundaries at some point in the future are possible.

Sea level rise in southwestern Dorchester County poses the greatest risk to DFS, because it involves loss and isolation of occupied habitat. However, even with these projected habitat losses, the area's remaining 58,398 ac of occupied habitat should continue to support the largest subpopulation, in terms of numbers and distribution, of DFS. This subpopulation's estimated total size exceeds the MVP size by over 50 times, even using the most conservative density estimates. This subpopulation has persisted and even grown over the past 40 years despite some rise in the level of Chesapeake Bay. Moreover, habitat in the northeastern portion of the county is connected to existing occupied forest farther inland. We also anticipate that DFS will move into a large tract of State-owned forest that will mature into DFS habitat in the next 10 years. Analysis of forest connectivity indicates that this area either already allows or will soon allow for DFS expansion, and it connects the Dorchester DFS subpopulation to forest tracts in Caroline and Sussex counties (Lookingbill *et al.* 2010). Although sea level rise may cause streams and rivers to widen and pose more of a barrier than they do currently, forested paths will still be available to provide DFS access to habitat in the inland portions of Dorchester County. Thus, losses in the southwestern portion of the county will likely be mediated by a population shift and persistence in the large interior portions of the county.

It is not clear how climate change may affect the forests of the Delmarva Peninsula. If climate change results in warmer conditions in the long term, the loblolly pine-dominated forests on the southern half of the Delmarva Peninsula may become even more predominant. However, since DFS occur in forests that range from all hardwoods to all pines and prefer a good mix of hardwoods and pines with diverse tree species, shifts in the species composition of these forests are not likely to be a significant threat for the squirrel.

In summary, DFS distribution has increased in the past 40 years even with some sea level rise occurring (approximately 1 ft in 100 years). In the next 40 to 50 years, under a worst-case scenario of a 24 in rise in sea level, we anticipate habitat losses affecting DFS populations in southwestern Dorchester County and along the Atlantic side of the Delmarva Peninsula, but we also anticipate population shifts toward and continued growth in the interior of the Peninsula. Thus, despite projected sea level rise, available data indicate that the loss of habitat due to sea level rise does not pose an extinction risk to the DFS.

2.3.2.1.3 Threat of habitat loss due to timber harvest

Unlike development and sea level rise, timber harvest does not result in a permanent loss of habitat. A timber harvest is followed by growth of a young forest, resulting in a landscape mosaic of mature and regenerating forest stands. As discussed in the previous status review (USFWS 2007) and in section 2.3.1.2 above, response studies indicate that DFS are resilient to timber harvests when there is adjacent habitat they can move into (Paglione 1996, Bocetti and Pattee 2003). The major threats posed by timber harvests are, therefore: (1) the prevalence of short-rotation timber harvests where trees are harvested before they mature enough to become DFS habitat, and (2) harvest rates that exceed growth rates and result in a continual decline of mature forest.

Threat from short-rotation pine forestry: Short-rotation pine forestry involves harvesting at approximately 25 years for pulp and other fiber products. Since it takes approximately 35 to 40 years to produce suitable DFS habitat, acreage harvested at 25 years never becomes suitable for DFS. In the past, Chesapeake Forest Products Corporation (Chesapeake) and Glatfelter Pulp Wood Company (Glatfelter) have been the main companies managing for short-rotation pine on the Delmarva Peninsula. However, these industries have effectively left the Peninsula, and in 1999 the State of Maryland acquired 58,000 ac of Chesapeake land to be managed for sustainable saw timber production and wildlife values. These lands consist of scattered parcels throughout the southern four Maryland counties (Figure 13). In addition, 10,384 ac of forest land previously owned by Chesapeake and managed for short-rotation pine are now owned by the State of Delaware. Land previously owned by Glatfelter Pulp Wood Company has also been put into an easement held by the State of Maryland (Vision Forestry, LLC 2004). All these lands, on which short rotations formerly precluded DFS habitat, will now be protected from development and managed for sustainable sawtimber production and wildlife. Thus, with management for sawtimber and wildlife, these 68,384 ac will provide habitat for DFSs into the long-term future.

Most of the former Chesapeake land is currently in early stages of succession; in 1999, 56 percent of the Maryland stands were less than 25 years old and 28 percent were greater than 35 years old (Maryland DNR 2010). However, within 10 years most of the forest land will be from 28 to 38 years of age. Moreover, about 5,844 ac of Chesapeake Lands are already occupied by DFS (CBFO GIS analysis 2010), and DFS management has been integrated into the Sustainable Forest Management Plan for Chesapeake Forest Lands (Maryland DNR 2010), which identifies a total of 23,534 ac as DFS Core Areas and DFS Future Core Areas; this is in addition to identified Ecologically Sensitive Areas, where management is for 60- to 80-year rotations. According to the management plan, at least 50 percent of the DFS Core Areas must be maintained in suitable DFS habitat at any one time, with a management emphasis on mature mixed pine/hardwood stands (Maryland DNR 2010). Thus, while most of the Chesapeake forest lands are currently unoccupied by DFS and are too young to provide breeding habitat, these areas are protected from development and will provide suitable DFS habitat in the near future. Overall, the Chesapeake lands represent a future of protected forest areas managed for sawtimber where DFS can persist and grow in numbers. The Chesapeake acquisition substantially removes the threat posed by short-term rotation pine management and provides a positive outlook for future habitat for the DFS on the lower shore.

Timber harvest across the landscape in the past: The 2007 status review (USFWS 2007) evaluated the threat from timber harvest using the U.S. Forest Service's (USFS) Forest Inventory and Analysis data (Frieswyk 2001) as well as a database of sediment and erosion control permits obtained from the counties. Although these data were the best available at the time, there was some concern about overestimating harvest based on permits issued. There was some evidence that individuals may obtain permits for timber harvest in case conditions are right to harvest, but then not actually conduct the harvest. This particularly appeared to be the case in Dorchester County. Consequently, since the 2007 review we have attempted to understand timber harvest rates in corollary ways as well (e.g., direct reports from State foresters in each county and LiDAR analysis). Each technique has some potential biases, and findings are not comparable or available over time to enable an understanding of trends. Thus, Table 6 shows estimated ac harvested in each county, reverting to sediment and erosion control permits simply because these data are collected in the same way over time. Note that the data for Sussex County, Delaware, where permits are not granted until immediately before the harvest, are considered to represent actual acres harvested on the ground.

Table 6 indicates that the average annual harvest in the most recent years preceding this review is substantially less than in previous years, according to the permit data base. In the southern Maryland counties, the average annual harvest has dropped by 1,000 to 2,000 ac (50 to 75 percent). Two northern counties, Queen Anne's and Caroline, have increased annual timber harvest by about 275 ac, which may reflect some shifting of the industry to northern counties. Nonetheless, the total amount of harvest across the eight Maryland counties appears to be greatly reduced. This is also the case in Delaware, where we consider the permit database to be very accurate. In Sussex County, the annual harvest rate in the last 4 years was half of what was generally harvested from 1998 to 2005.

Not only has the total annual harvest acreage declined, so has the size of individual harvest areas. In the mid to late 1990s, the typical size of timber harvests ranged from 30 to 70 ac, while over the past 5 years, the average size of timber harvests ranges from 22 to 48 ac. For instance, in Dorchester County, the size of timber harvests described in the permits averaged 70 ac from 1994 to 2005 and 47 ac from 2006 to 2009. In Somerset County, the average size of clearcuts was 49 ac from 1994 to 1999, and 27 ac from 2005 to 2009 (Table 6).

The reasons for this overall reduction in timber harvests probably include many economic events, and closure of several sawmills was occurring even before the 2008 recession. The market for timber has declined dramatically, and prices for timber remain very low, reducing incentives to harvest. As discussed below, additional factors suggest that reduced harvest levels are likely to continue in the future.

Future threats posed by timber harvest: Although it is highly difficult to predict future market forces, several trends suggest future timber harvests might remain smaller in size and occur less frequently. An assessment of forests in the Chesapeake Bay area (Sprague *et al.* 2006) refers to trends in fragmentation and parcelization of forests. Parcelization is the subdivision of large blocks of land into multiple ownerships. As forest lands are subdivided, landowners tend to change from management of their woodlands for timber to management for aesthetics and wildlife values. The National Woodland Owner Survey conducted by the USFS found that in Maryland 45 percent of the woodland owners own less than 50 ac of woods (http://fiatools.fs.fed.us/NWOS), whereas most clearcuts in the past were 40 to 50 ac in size.

Thus, almost half of the woodland owners do not own enough to accommodate an average clearcut without losing all of their woods. These owners are not likely to be managing for timber as a source of income. This ownership pattern also reflects the "gentrification" of the shore, with landowners becoming less likely to be farmers or foresters and more likely to be commuters or retirees that do not earn their living from the natural resources on their properties. Although these landowners may harvest small portions of the woods, they are likely to retain some wooded stands as well. This continued parcelization and gentrification is expected to reduce the number of landowners managing for timber values, reduce the size of timber harvests, and result in an overall reduction in the total acres harvested. This trend is already apparent in the reduced average size of timber harvests indicated by the sediment and erosion control permit databases discussed above and in USFWS (2007).

In summary, the threat posed by short-rotation pine timber harvests has largely been eliminated by the transfer of the 58,000 ac to the State of Maryland to be managed for sawtimber and wildlife habitat, along with state management of other areas previously harvest for pulpwood. In addition, the timber harvest rates on private lands across the eight Maryland counties have declined dramatically in the past several years. Furthermore, future timber harvest on the shore is likely to be more limited than it has been in the past because of changes in the timber market and landownership patterns. And, importantly, the transfer of the Chesapeake and Glatfelter timber lands to Maryland and Delaware will provide significant long-term conservation benefits for the DFS. These land transfers, in conjunction with available data on harvest rates across the range of the squirrel, suggest that timber harvest does not pose an extinction risk for the DFS.

2.3.2.2 Factor B. Overutilization for commercial, recreational, scientific or educational purposes

Overhunting has been posited as a factor in the original decline of this species. Squirrel hunting was common in the early and middle decades of the 20th century, and, given the DFS's larger size and tendency to be on the ground, they may have been preferred game over gray squirrels. Squirrel hunting was also a common way for young hunters to gain experience. Taylor (1976) noted that DFS appeared to persist on large agricultural estates where hunting was not allowed and suggested that these areas may have provided a network of refugia for DFS as the species became extirpated elsewhere. It is also likely that hunting of DFS in small, isolated woodlots or narrow riparian corridors could have resulted in local extirpations.

Hunting in the past 40 years: Hunting of DFS was banned in 1972. Removal of hunting pressure, combined with other factors, may have allowed renewed population growth and expansion of the squirrel's range to its current extent. Coincidentally, squirrel hunting has declined in popularity in recent decades and has been replaced largely by deer hunting. Nationwide, squirrel hunting declined by 41 percent from 1991 to 2001 (USFWS 2001), along with an overall decline in the number of citizens hunting (Organ and Fritzell 2000). Across Maryland, the number of hunters pursuing gray squirrels declined by almost half in just the 5 years from 2000 to 2005, from about 19,000 to 10,000 hunters, while the number of hunters pursuing fox squirrels (*Sciurus niger rufiventor*) in western Maryland dropped from about 3,000 to 1,800 (www.dnr.state.md.us/wildlife/gpar/gpfur_table1.asp). Although some hunters may mistake DFS for gray squirrels (despite educational efforts to help hunters differentiate between the two), this is likely a rare situation that has not prevented the DFS from expanding over the last 40 years.

Projected hunting trends: Discussions with our State partners suggest that DFS management after delisting would be conducted very carefully and that a hunting season would not be opened in the immediate future. The DFS are likely to continue to be included on State lists of species with some conservation need. We recognize that a very restricted hunt could be conducted in the future at sites where DFS are abundant without causing a population decline. State management agencies have the capability to implement careful hunting restrictions and population management and the reopening of the black bear hunt in Maryland is a good example of a very carefully managed hunt (http://www.dnr.state.md.us/huntersguide/BlackBearHunt.asp).

We nonetheless foresee only limited public interest in reinitiating a DFS hunt, coupled with strong public attitudes against hunting DFS. Public sentiment toward hunting in general has changed, whereby hunting for food, management of game populations, and animal population control are considered to be acceptable activities, whereas hunting strictly for recreation is considered less acceptable (Duda *et al.* 1995). Given public attitudes, the declining interest in squirrel hunting, and the restrictions that would almost certainly be imposed on a renewed hunting program, hunting is highly unlikely to pose an extinction risk to the DFS.

2.3.2.3 Factor C. Disease or predation

Predation: Predators of DFSs include red fox (*Vulpes vulpes*), gray fox (*Urocyon cinereoargenteus*), red-tailed hawks (*Buteo jamaicensis*), bald eagles (*Haliaeetus leucocephalus*), and possibly domestic pets and feral animals (e.g., cats and dogs). Owls are probably not major predators, as camera surveys have found that DFS activity patterns rarely include dawn or evening hours, although the gray squirrel is active at these times. Morris (2006) found 90 percent of camera detections occurred from 8 a.m. to 5 p.m.

Changes in predator numbers may cause some fluctuations in DFS numbers at a site (for example, a DFS population may decline when red fox populations increase), but these types of events are sporadic and localized. Likewise, bald eagle numbers have dramatically increased in the Chesapeake Bay region over the past 40 years, but although they have been known to take DFS, they still prey primarily on fish. Overall, DFS have evolved with mammalian and avian predators and there is no evidence that natural predation poses a threat.

Anthropogenic sources of predation include domestic pets and feral animals. Predation by domestic or feral dogs and cats may be one reason DFS are not typically found in suburban settings; however, such predation is not considered to be a rangewide threat. There is also some evidence that avian predation may increase in areas where forests have been thinned just prior to harvest (Paglione 1996). Overall, however, the DFS population has increased over the last 40 years despite predation, and predation is not seen as either a current or future extinction risk for the species.

Disease: Documentation of disease in DFS is uncommon. The cause of death was described for 15 of 63 animals submitted to the Madison Health Lab, and of these 15 animals only 5 were documented as succumbing to infectious disease; the only diseases identified were leptospirosis and erysipelas, both of which are bacterial infections. Other subspecies of eastern fox squirrels are known to carry disease. For example, mange has been documented in the Big Cypress fox squirrel (*Sciurus niger avicennia*) (www.dickbrewer.org), and rabies has been found in eastern fox squirrels that were introduced to California (Cappucci *et al.* 1972). There is no documentation of these diseases in DFS, however, and there is no evidence or suspicion of disease-related declines in any local population.

Nonetheless, the recent advent of white-nose syndrome affecting bats (Blehert *et al.* 2009) and chytrid fungus affecting amphibians (Daszak *et al.* 1999) demonstrates the uncertainty surrounding novel disease events. Neither of these events is well understood, and they are causing major population effects for many bat and amphibian species. The life history traits of the DFS, however, make them less susceptible to these types of epizootics. The DFS does not congregate in large numbers (like bats in hibernacula), where disease can easily spread through a population. Further, early records describe the DFS as patchily distributed across its range (Taylor 1976), and this continues to be the case. This patchy distribution makes it more difficult for disease to spread through the squirrel’s range. Finally, DFS are not migratory nor in an environment (like aquatic species) where pathogens can readily disperse.

Inasmuch as neither disease nor predation has prevented the DFS from persisting and expanding its distribution and as the species' life history traits may forestall unanticipated disease outbreaks, there is no indication that disease or predation poses an extinction risk.

2.3.2.4 Factor D. Inadequacy of existing regulatory mechanisms

Existing regulatory mechanisms must be considered with respect to how adequately they will protect DFS from declining toward endangerment after ESA protections are lifted. Although historical land use and hunting regulations were clearly inadequate in terms of preventing the original decline of DFS, many State laws and programs have been enacted since the species was listed. We assess the conservation benefits of these programs to DFS and whether they will be adequate for protecting the squirrel after delisting.

The DFS is listed as endangered by all three States in which it occurs, and is therefore currently protected, albeit to varying degrees, under State endangered species laws. In Maryland, all species listed as endangered or threatened under the ESA are State-listed, and conservation of these species closely follows Federal programs. Delaware has a limited endangered species act that provides for State-listing and restricts trafficking of listed species; penalties include fines or jail or both. Virginia has separate laws that cover endangered plants and animals; for animals, listings are based on scientific evidence only and penalties for take include fines or jail or both. As with Maryland, federally listed species are included on Delaware and Virginia State lists, and when the Service removes species from the Federal list, the States may or may not remove them from their lists. In Maryland, the DFS could remain on the list of Species of Greatest Conservation Need (Maryland DNR 2005) even after delisting, which would enable continued protection through the Maryland Critical Area Law and continue to focus conservation efforts on the species. While discussions with our State partners suggest conservation of DFS would continue to some extent after delisting, it is appropriate to consider what other laws or programs would act to conserve this species after delisting in lieu of such efforts.

Several laws in Maryland established over the past 40 years provide substantial protections for DFS habitat. The Maryland Critical Areas Act, the State-implemented portions of the Clean Water Act, which protects wetlands, and the Maryland Forest Conservation Act have all proven to be effective long-term mechanisms for preserving forest land and DFS habitat in the State (see Appendix D).

Maryland Critical Areas Act: The regulatory requirements of this law apply to land within 1,000 ft of mean high tide. In these areas, there can be no clearing of forest or any building within 200 ft of the shoreline (the law was amended 2008 to increase the buffer size from 100 to 200 ft). Thus, the forest along the Chesapeake Bay and its tidal tributaries will remain undisturbed for at least 200 ft, and since this applies to both sides of tidal tributaries, it provides substantial protection for riparian forests. This law also requires that any losses of forest outside the 200-ft buffer but within the Critical Areas must be balanced with afforestation, meaning that the total amount of forested land within the Critical Areas should not change. These requirements effectively conserve a great deal of the riparian and shoreline forest habitat and important travel corridors currently used by DFS. This law also requires review of timber harvests planned within the 1,000-ft Critical Area zone and requires that conservation measures be implemented for endangered species. In the past, the timber harvest recommendations described in the 1993 recovery plan (USFWS 1993) have been implemented on harvests within the Critical Area; implementation of these recommendations would continue if the DFS remained as a Species of Conservation Need.

Maryland Forest Conservation Act: This State law protects forested areas outside the Critical Areas. It basically requires that any project involving clearing of forest for homes or transportation mitigate the loss through afforestation and provision of easements to protect the remaining forest on site. It thus functions to minimize the amount of forest clearing that occurs in a project area and assures that the forest retained on site will not be further developed. These protections will support the continued movement of DFS through the landscape even after delisting.

Clean Water Act: State implementation of this law likely provides the most significant forest protections, simply because forest lands remaining on the eastern shore of Maryland and in many areas of Delaware contain a preponderance of forested wetlands. This is generally because the forests present today were too wet to farm in the past and were thus not converted to agricultural uses. Development proponents now have a great deal of incentive to avoid both wetlands and clearing of forests; thus, most housing developments are constructed on agricultural fields rather than in wooded areas. This is especially true if the development requires soils that are sufficiently well drained to support septic fields. This pattern is expected to continue for the foreseeable future.

In addition, under Factor A (section 2.3.2.1.1), we described the several State programs that incentivize conservation easements that protect lands from development. There are currently over 200,000 ac of private land protected from future development (see Table 3) through programs such as the following. The ***Maryland Agricultural Land Protection Fund*** is designed to protect the best farmland from development and currently protects 112,000 ac across the eight Maryland counties. Easements are placed on entire farms which include agricultural lands and forest lands. The ***Maryland Environmental Trust (MET***) holds voluntary easements that prevent development on almost 60,000 ac of private lands in the eight-county area. The ***Rural Legacy program*** is designed to specifically offset the development that is expected in Smart Growth areas. Delaware also has an Agricultural Land Protection Program and a Forest Legacy Program, and though these started later than in Maryland, they have already protected over 30,000 ac in Sussex County.

Growth in these programs has also been impressive. The rate of growth in land protection for each county is illustrated in Chart 2 (see section 2.3.1.1.3). If Federal and State lands are added to this protected land base, more than 500,000 ac of land are protected from development (see Table 3).

In summary, we conclude that the inadequacy of existing regulatory mechanisms does not pose an extinction risk to the DFS.

2.3.2.5 Factor E. Other natural or manmade factors

Forest pests: Gypsy moth and pine bark beetle outbreaks can decimate mature forest stands, although the affected stands will eventually regenerate. The last major gypsy moth outbreak in Dorchester County was in the early 1990s, and, because gypsy moths have cyclic populations, another outbreak was anticipated (Maryland Forest Health Highlights 1997). However, gypsy moth control through monitoring and spraying appears to have reduced this threat on the Eastern Shore; infestations in the last several years have diminished in acreage and were primarily in other parts of the State (Maryland Forest Health Highlights 2007, 2008, 2009). In the last 20 years, we can total the number of acres defoliated in the eight Maryland counties over four time periods: 1991 to 1996, 1996 to 2000, 2001 to 2005, and 2006 to 2010. The acres defoliated in those time periods have declined from 304,527 acres to 17,580 acres, 23,944 acres, and 203 acres, respectively (data provided by Maryland Department of Agriculture, Forest Pest Management Section; email of September 29, 2011). Clearly, gypsy moth infestations are no longer a prime concern.

Pine bark beetle infestations necessitated salvage cuts for a total of 2,000 acres scattered across Somerset, Dorchester, and Worcester Counties in the early 1990s, but monitoring and control efforts appear to have reduced this threat as well. An analysis of forest pest risk across counties in the Chesapeake Bay watershed found that most areas on the Eastern Shore where DFS occur have relatively low risk for insect infestations, with most having 3.8 to 10 percent of their area considered to be at risk (Sprague *et al.* 2006).

Although emergence of new forest pests is to be expected, the Maryland Department of Agriculture has a Forest Health Monitoring Program that conducts surveys to map and report forest pest problems (http://www.mda.state.md.us/plants-pests/forest_pest_mgmt/index.php). Aerial and ground surveys, data collection, and reporting are conducted in cooperation with the USFS monitoring program. For example, the Cooperative Gypsy Moth Suppression Program is conducted by the Maryland Department of Agriculture in cooperation with the USFS and county governments, and bark beetle monitoring has been conducted through pheromone-baited Lindgren funnel traps. Thus, State and Federal programs are conducting work cooperatively to address early detection of pests and develop control techniques.

Forest pest outbreaks are likely to recur and may increase with climate change. However, this threat appears to be localized and sporadic and, with existing programs to monitor and treat forest pest outbreaks, does not pose an extinction risk for the DFS.

Vehicle strikes: Vehicle strikes are a relatively common source of DFS mortality. Like with other species, the probability of DFS being hit by vehicles is dependent on the density of DFS in the area and the proximity of the road to habitat. The frequency of roadkills has been shown to reflect general patterns of abundance of many species over large geographic areas or time periods. For instance, various studies found roadkill abundance comparable to abundance identified using other survey methods for raccoons (Gehrt 2002), porcupines (Earle and Kramm 1982), pheasants (Case 1978), and white-tailed deer (McCaffery 1973). For these reasons, roadkill frequency has also been used as an index of comparative abundance over time or between large areas such as counties (Case 1978, Mallick *et al.* 1998).

Vehicle strikes of DFS tend to be reported more frequently in areas where DFS are abundant, even if traffic levels are relatively low (e.g., Dorchester County). The conscientious reporting and collecting of DFS killed on roads at the Blackwater and Chincoteague NWRs, where DFS are very abundant, likely results in a more complete count of vehicle strikes than elsewhere. Vehicle strikes regularly occur at both refuges, yet DFS remain common or abundant in both refuges despite the vehicle strikes. There may be landscape features that increase the chance of roadkills in certain areas. For instance, multiple roadkills have been documented at locations where a large woodland is on one side of the road and a hedgerow leads away from the road on the other side; these hedgerows or even ditches may be used as common travel corridors, and squirrels may thus be at those locations more frequently. The refuges have manipulated habitat along the edges of the road to reduce roadkill. For example, at Blackwater NWR, a wider buffer was grown between the road and agricultural crops along Key Wallace Drive where DFS were crossing from woods to agricultural fields on the other side of the road. Chincoteague NWR has mowed wider areas along the roadsides to enable a better view of DFS by drivers. More study may identify other ways to potentially reduce DFS roadkill on refuges and elsewhere. Despite these local events, however, DFS populations continue to persist and expand, and vehicle strikes alone do not appear to be a pervasive threat or an extinction risk for this species.

2.4 Synthesis

2.4.1 Synthesis of five-factor analysis

The analysis provided in the previous portions of this document indicates that no individual factor is considered to threaten this species with extinction now or is likely to threaten this species with extinction in the foreseeable future. In this section, we attempt to synthesize these individual factors together to assess their cumulative effects into the future (Table 7).

The first three columns of Table 7 provide the following: (1) the acres of occupied forest in 2010 in each subpopulation, (2) the acres of occupied forest remaining after all anticipated losses from both development and sea level rise, and (3) the acres of occupied forest remaining after all anticipated losses and expected gains from discovery. Note that we are using an exaggerated loss of habitat from sea level rise in this table, anticipating 2 feet of sea level rise occurring in 40 years. We are also using a conservative estimate for expected rate of discovery of occupied habitat by taking the actual observed rate of increase from the past 10 years (1,887 ac per year), and projecting increases to occur at half that rate (944 ac per year across the range). For example, the Dorchester/Nanticoke subpopulation is projected to incur the greatest habitat losses because of sea level rise. The habitat is reduced from 95,725 ac to 58,398 ac of occupied forest after all losses, or about 61 percent of the occupied forest present in 2010, if all losses from sea level rise occur by 2030 and there are no gains in occupied habitat (worst case scenario). If we also include the expected addition of some newly discovered occupied habitat over that same 20 years, we would expect 70,204 ac of occupied forest by 2030. Currently, the 95,725 ac of occupied forest in the Dorchester/Nanticoke subpopulation has about 48.3 percent in a mature forest stage suitable for DFS. This corresponds to 46,044 ac of *occupied mature forest* (95,725*0.481). Given that the average density of DFS in Dorchester is 0.33 DFS per ac, this would indicate there are about 15,194 DFS in this subpopulation. There are 130 animals in our estimate of a MVP from the PVA model (Hilderbrand *et al.* 2007). By dividing the estimate of 15,194 DFS by the

MVP size of 130 DFS, we would conclude that the current population is 117 times the size of the MVP. And even if all losses occurred by 2030 and *no gains in occupied forest occurred*, the remaining 58,398 ac of occupied forest is still sufficient to support 71 times the MVP.

If we consider the acres of forest currently occupied in each subpopulation and subtract the expected losses in occupied forest from development and sea level rise, *and even if we do not add the expected forest growth,* we still retain highly viable subpopulations. In Table 7, with all losses and no future growth, 95 percent of all the DFS are in the 11 largest subpopulations, all of which are considered "likely to persist" because they have at least one MVP. Given that some new occupied forest is likely to be discovered, as it has in the past, and many of these subpopulations are likely to join together, the more realistic expectation is that most of these subpopulations will persist, with two expected extirpations. The most likely areas for growth are the areas between the four largest subpopulations as well as the Somerset County area. As subpopulations become further connected, their likelihood of extinction becomes even more remote.

In Table 7 we provide our conclusion on likely persistence of the current subpopulations based on their size and isolation with losses and gains. Two subpopulations that are already isolated are likely to become extirpated. Other smaller and isolated subpopulations that resulted from translocations are more vulnerable than others and might or might not persist. The DFSs in some of the translocation area are also becoming harder to track because in some cases they have moved into different woodlands, and in large tracts of forest it can be difficult to find DFS. However, 95 percent of the anticipated population in 2030, with all the losses and gains occurring in the next 20 years, occurs in the 11 largest subpopulations that are most secure.

Taken individually, no one threat is considered to endanger or threaten this species with extinction and taken together, they do not endanger or threaten this species with extinction. Over the past 40 years, the species' range has expanded, translocations continue to be successful, and additional populations have been discovered. This has occurred despite increases in developed land, ongoing timber harvest, and some sea level rise. During this time period, the hunting season on DFS was closed and the implementation of many State laws have enhanced and protected forested areas in the DFS range. In the next 40 years, these laws will continue to protect habitat, and we anticipate that the range of the DFS will continue to expand through discovery and colonization despite some losses from development and sea level rise.

We anticipate that there will likely be additional populations of DFS discovered in the future, just as in the past, and that these discoveries will likely connect the current DFS subpopulations which will become larger areas of connected occupied forest (as has happened between the last and present status review). This will further decrease the likelihood of extinction. There is mature forest in areas between subpopulations where DFS may yet be discovered. And though some small subpopulations near expanding urban areas are likely to become extirpated, the majority of the population is in areas that are very likely to persist, have forested areas to expand into, and are not threatened by development.

Chart 5. Summary of five-factor analysis.

Factor	Trends in past 40 years	Foreseeable trends in next 40 years	Does factor threaten or endanger the DFS?
Habitat loss from development	In the past 40 years, development increased from 3 percent to 8 percent of the eight Maryland counties; development has increased in Sussex County as well. Some habitat has been lost, but most development occurs near existing towns where DFS are not as prevalent, and development often occurs on agricultural land rather than forest land.	Development is expected to increase to 14 percent of the land area in the 8 Maryland counties and in Sussex County as well. Most projected development will occur near urban areas where DFS do not currently occur (e.g., Salisbury). However, 3 to 4 percent of the total DFS occupied habitat is expected to be lost to development. While these losses may cause some small subpopulations to disappear, the majority of the currently occupied habitat will continue to be available. The DFS distribution is expected to continue to grow despite this development as it has in the past.	NO
Habitat loss from sea level rise	In the past, losses in occupied habitat have occurred in southern Dorchester County, though the acreage is not known. Sea level rise has occurred in the past at the rate of 3.5 mm per year (about 1 ft per 100 years).	Under an extreme scenario of 2-ft inundation in 40 years, 23,060 ac will be lost or isolated and 14,267 ac of fringe habitat will deteriorate in southwestern Dorchester. However, this still leaves this subpopulation with an estimated 71 times the MVP size. The Dorchester subpopulation would continue to be the largest subpopulation and be very likely to persist.	NO
Habitat loss from timber harvest	Sawtimber harvest has occurred throughout the Peninsula. The harvest rate in Dorchester County was 2,291 ac per year. This estimate (possibly an overestimate) appears to have been sustainable as the DFS have increased their distribution in Dorchester and elsewhere despite this.	Recent declines in timber harvest rates and mill closings may reduce the harvest rate for some time. Increasing parcelization of land will reduce the opportunities for large-scale timber production. Gentrification of the Eastern Shore will likely shift public values for forest management from timber production to management for aesthetics and wildlife.	NO
Habitat loss from short-rotation pine	In the past, short-rotation pine harvests have occurred on approximately 58,000 ac of the eight Maryland Counties and	Since, 1999, these lands have been obtained by the State of Maryland and Delaware and are now managed for	NO

	10,000 ac more in Sussex County, Delaware. These acres were typically harvested before they were mature enough to be DFS habitat.	sawtimber which will provide suitable DFS habitat. Thus, we now have 58,000 ac of land protected from development and managed for sawtimber, enabling use by DFS that was previously prevented.	
Overutilization	Hunting seasons were closed.	Hunting seasons are likely to remain closed. If opened, they could be very limited and managed very carefully. Interest in squirrel hunting has declined significantly, and public attitudes towards hunting have changed to primarily support hunting species viewed as needing population management such as deer.	NO
Disease or Predation	Disease and predation have not been significant threats for this species in the past 40 years.	These threats are not expected to increase, and the increasing distribution of the DFS lessens the impact that disease and predation could have on this species.	NO
Other regulatory mechanisms	Many new MD laws have appeared in the last 40 years to help conserve forest areas (see Appendix D). DFS occurrences in Delaware and Virginia have been primarily on protected lands.	In the next 40 years forest conservation measures are expected to continue, and they may be improved and possibly added in Delaware or Virginia. Delaware has limited regulations for private lands currently, but most DFS are on public lands, and these can continue to be managed for DFS. Some additional programs are beginning in Delaware (agricultural easement program). The sole Virginia population is on fully protected land.	NO
Other natural or manmade factors	Forest pests and vehicle strikes have occurred in the past 40 years to some extent but have not limited the expansion of the DFS distribution.	Forest pests and vehicle strikes are likely to continue to occur to some extent, but these factors have not limited growth of the subpopulations in the past and are not expected to in the future. As populations increase in density, vehicle strikes could increase as the probability of vehicle strikes is primarily a function of animal abundance. But this has not limited population growth in the past.	NO

2.4.2 Biological principles of representation, redundancy and resiliency

We can also evaluate the status of the current rangewide population distribution under the biological principles of resiliency, representation, and redundancy, often called the "3 Rs" (after Shaffer and Stein 2000, and Redford *et al.* 2011). While these concepts underlie the preceding assessments in this document, we address them more specifically here. These concepts address various aspects of a species' viability, that is, its ability to persist over the long term and conversely to avoid extinction over the long term. Groves (2003) defined the 3 Rs in the context of designing a conservation plan and their relevance to ascertaining overall viability. We define these terms relative to the status of species, as follows: resiliency is defined as the ability of the species to withstand stochastic events; representation is defined as the ability of a species to adapt to changing environmental conditions; and redundancy is defined as the ability of a species to withstand catastrophic events. We refer to both Groves (2003) and our definitions to assess how the DFS populations reflect these biological principles.

Resiliency. "Conservation targets …should be resilient to both natural and human caused disturbances" (Groves 2003). This ability of the species to withstand stochastic events is clearly important for long-term viability. It is best demonstrated by long-term persistence of populations throughout the range, as this reflects the species' ability to continue despite natural and human-caused disturbances. Has the DFS rangewide population demonstrated resilience to past threats, and is this resilience likely to continue?

First, there are aspects of this species' life history that convey resilience in the past and in the future. The DFS uses a wide range of mixed forests types that may be dominated by hardwoods or conifers. While they need some mature forest, their diets are diverse, and they travel and forage in many areas including clearcuts, young forest, and agricultural fields. They will move through many habitat types as they travel across areas, and individuals have been known to move 5 mi in one direction. As members of the Order Rodentia, they have life histories with good potential for population increase; for example, females breed at 1 year of age, litter sizes range from 2 to 4 young, there is potential for two litters in 1 year by some females, and life spans can reach 6 to 7 years in the wild. Their overall tolerance of timber harvests by generally shifting home ranges to adjacent habitat (Paglione 1996, Bocetti and Pattee 2003) indicates that natural and manmade disturbances that set forest succession back can generally be tolerated. In addition, the success of the translocations is a demonstration of their ability to persist and grow from relatively small populations (see Table 1). Finally, the long-term persistence of DFS in at least 91 percent of the woodlots over the last 20 years (see Chart1) and the persistence of DFS occupancy in the Taylor sites from 1971 to 2001 (Therres and Willey 2005) demonstrate the species' ability to persist despite the stochastic events that occur on this landscape.

Representation. "Conservation areas in the region should represent the biological features and range of ecological conditions …" (Groves 2003). When a species occurs in a variety of ecological conditions, it reflects underlying genetic diversity, which enhances the species ability to respond to any future changes in environmental conditions (USFWS draft policy). Thus, for the DFS, we can evaluate whether the current distribution includes a range of environmental conditions.

As stated previously in this document, the forests of the Delmarva Peninsula range from hardwood dominated forests in a primarily agricultural landscape in the northern half of the Peninsula, to pine dominated forests in a more forested landscape in the southern half. There are many stands of mixed pines and hardwoods throughout the Peninsula and the DFS distribution includes all forest types. The current distribution of the DFS includes persistent occupancy of the hardwood-dominated forests of the northern four Maryland counties and Sussex County, Delaware and persistent occupancy of the pine-dominated forests in the southern Maryland counties. The DFS is not a narrow niche species, and it is well-distributed throughout the continuum of hardwood- to pine-dominated forests that occur throughout the Peninsula. It also occurs in the full range of wetland to upland forest types. Wetland forest types occur throughout the Delmarva Peninsula and the coastal areas of the southern four counties. The DFS is very abundant in the wet forests of southern Dorchester, but it is also very abundant in the more upland forests found in other areas of Dorchester and Talbot Counties and occurs in the full range of forest types in all portions of the range. There are a few subpopulations on the Atlantic coastal areas (e.g., Prime Hook, Jarvis, and Chincoteague) that were established through translocations. There is no information in the historical records that suggest that the DFS were associated with coastal areas specifically, and with the exception of Chincoteague, the populations in the Atlantic coastal areas occur in mature mixed forests that appear similar to the mature mixed forests of more inland areas; thus, we do not consider "coastal areas" to be a meaningful niche to represent. However, the fact that these translocations are continuing to be successful suggests these environmental conditions are not substantially different or are at least within the range of conditions that DFS can inhabit. Overall, DFS successfully inhabit a variety of environmental conditions including wetland and upland forests, pine-dominated and hardwood-dominated forests, and inland and coastal areas. Persistence of populations within this range of conditions suggests sufficient genetic plasticity to adapt to some future variation in environmental conditions.

Redundancy. "To avoid extinction or endangerment caused by both naturally occurring stochastic events (e.g., disease, predation, floods, fire) and human-related threats, conservation targets should be represented multiple times…" (Groves 2003). Redundancy enhances viability because it spreads out the risk of catastrophic events, and if a catastrophe caused extinction in one location, there are other populations that can continue to persist. For the DFS, is there redundancy in the populations across the landscape so that some extirpations of woodlots or areas would not threaten the species with extinction?

The DFS occurs in 22 subpopulations as identified in this status review. While these subpopulations provide one example of the redundancy found within the rangewide population distribution, redundancy can also be considered as the many patches of occupied forest that occur throughout the range. We have already observed how new areas of occupied forest can be discovered and provide links between subpopulations (several have merged since the 2007 Review) and more subpopulations are expected to merge over time. The overall number of subpopulations is expected to decline as new DFS sightings occur between them, but the number and acres of occupied forest blocks are expected to increase. Thus, a catastrophic event such as a tornado, winter storm, or hurricane that causes destruction of several forest blocks likely would not cause extinction of the species because there are many more forest blocks where DFS would remain. In addition, the growing connectedness of the rangewide population enhances the probability for "rescue" or re-colonization of a woodlot from surrounding sources of persisting DFS. Overall, there is redundancy in the number of counties where the DFS occurs and the number of subpopulations, but most important, there is redundancy in the number of woodlots that are occupied by DFS, and this redundancy enhances the long-term viability of this species.

Resiliency, Representation, and Redundancy Summary: The DFS's life history conveys considerable resilience to stochastic events, and its persistent occupancy of woodlots over the past 20 to 30 years demonstrates this. The success of the translocations demonstrates the species' ability to start new populations from fairly small numbers of animals. Its long-term persistence in a wide range of forest types from hardwood-dominated to pine-dominated forests and from wetland to upland forests indicates underlying genetic variability or behavioral plasticity that would enhance its viability under changing environmental conditions. The DFS's redundant occurrence and persistence in woodlots across the landscape ensures their ability to withstand catastrophic events that may extirpate some areas. If the DFS was extirpated from some areas, it would be expected to continue in many other woodlots and may be able to re-colonize some areas after conditions improved. The rangewide population of DFS is expected to persist and grow and continue to occupy the full complement of landscape and forest types.

2.4.3 Significant Portion of its Range analysis

Having determined that the DFS is not in danger of extinction or likely to become so in the foreseeable future throughout all of its range, we must next consider whether the species is in danger of extinction or is likely to become so in the foreseeable future in any significant portion of its range.

A portion of a species' range is significant if it is part of the current range of the species and if it is important to the conservation of the species because it contributes meaningfully to the representation, resiliency, or redundancy of the species. The contribution must be at a level such that its loss would result in a decrease in the ability to conserve the species. Applying the definition described above for determining whether a species is endangered or threatened in a significant portion of its range, we first addressed whether any portions of the range of DFS warranted further consideration. As a starting point for subdividing the species range, we first looked to the recovery plan to determine if it identified any areas that would qualify as a significant portion of the range. The recovery plan does not identify any separate areas of the range as significantly different from others.

There are areas where DFS are likely to be extirpated. These include areas in Queen Anne's County near the 301 and 50 split and possibly areas of occupied forest near Centreville in Queen Anne's County. This is an area where the DFS distribution is scattered and somewhat isolated by roads and water, and future development is anticipated. However, in the past 5 years there has been newly discovered occupied forest in this area. While the distribution is somewhat scattered, we have identified new sites that are filling in the distribution and making greater connectivity between the sites. But if this trend was reversed and we lost some sites in this area, would it be a significant portion of its range and does it contribute meaningfully to the representation, resiliency, or redundancy of the species? We examine this question below.

Queen Anne's Counties landscape is similar to Kent, Talbot, and Caroline Counties in that it has hardwood-dominated forests in a landscape of primarily (60 percent) agricultural land with only 27 percent forested (Table 2). Five secure subpopulations that are large and "expected to persist" occur in the northern four counties of Maryland (e.g., Tunis Mills, Wye Mills, Carmichael Road, Wye Island, and Southern Talbot). These populations would certainly function to represent the DFS in the northern, hardwood-dominated and more agricultural counties. We also consider these to be resilient to the proposed threats and their combined area provides redundancy. However, the loss of some of the small areas of occupied forest in Queen Anne's would make a greater gap between the large populations of Carmichael Road and Tunis Mills, and the more distant subpopulation to the north at Chino Farms. Does this make Chino Farms more vulnerable? This subpopulation is already isolated from the other small subpopulations. The Chino Farms DFSs were discovered fairly recently (1999) and continue to be sighted but are not considered to be abundant yet on the property. However, the DFS occur here on a large tract of forest that is protected from development. We anticipate the DFS at Chino Farms to continue to grow on this protected land, and its persistence does not appear to be dependent on the DFS in the Centreville area. Thus, if we look at the current 22 subpopulations, we might anticipate some losses in the Queen Anne's County area where several small, isolated populations may become extirpated by development or just small size; however, these are not considered to represent a significant portion of the DFS range.

We also expect losses of DFS occupied forest from sea level rise in southwestern Dorchester County. Does this area represent a significant portion of its range? The losses in this area are on the southwestern edges of the Dorchester/Nanticoke subpopulation. This is currently the largest subpopulation. As previously described, these losses do not threaten the subpopulation with a risk of extinction as there would continue to be enough occupied forest remaining to support 87 times the MVP value for DFS. The area lost from sea level rise is therefore not a significant portion of the DFS range.

In summary, a portion of a species' range is significant if it is part of the current range of the species and if it is important to the conservation of the species because it contributes meaningfully to the representation, resiliency, or redundancy of the species. The potential losses that may occur in small areas of Queen Anne's County do not qualify as significant portions of the range because they do not cause cascading vulnerability or reflect unique areas that are not represented elsewhere in the species' range. Similarly, the area of Dorchester County anticipated to be lost to sea level rise is also not considered to be a significant portion of the species' range because it does not threaten the continued survival of the Dorchester subpopulation, and DFS will remain present in coastal forests in Dorchester and other areas even after these losses.

3.0 RESULTS

3.1 Recommended classification: Delist

As explained in the Synthesis sections above, the DFS does not meet the definition of an endangered or threatened species under the ESA based upon the best information available. The populations have increased in number and distribution over the last 40 years. This increase, which has resulted from successful translocations that are now expanding on their own, as well as from natural expansion or discovery of natural populations that are not a result of translocations, is expected to continue in the future. The threats considered here are not considered to threaten or endanger this species with extinction now or in the foreseeable future. Having determined that the DFS is not in danger of extinction or likely to become so in the foreseeable future throughout all of its range, we also do not consider this species to be in danger of extinction or likely to become so in the foreseeable future in a significant portion of its range. Its current population viability and distribution provide for appropriate representation, redundancy, and resilience to enable this species to persist and grow.

Overall, our analysis of the five factors, either alone or in combination, indicates that the DFS is not in danger of extinction throughout all or a significant portion of its range and is not likely to become so within the foreseeable future.

3.2 Recommended Recovery Priority Number: 15C

All listed species require a Recovery Priority Number (RPN). Thus, until the DFS is delisted through a final rulemaking, we recommend retaining the current RPN of 15C. This ranking is indicative of a subspecies facing a low level of threat and having a high potential for recovery. It should be noted that although economic conflict (indicated by the "C") still occurs, it does not rise to the level of an extinction risk, as discussed in the Review Analysis above.

3.3 Recommended Delisting Priority Number: 2

The DFS meets the criteria for a Delisting Priority Number of 2; that is, an unpetitioned action that will significantly reduce management and regulatory burdens.

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

Action 1: Prepare a post-delisting monitoring plan that employs monitoring protocols and methods similar to those used to detect the long-term presence of DFS and available habitat for purposes of recovery, as described in section 2.3.1.1 of this review.

Action 2: Prepare a proposed delisting rule.

Action 3: As long as the DFS remains listed, continue to implement monitoring, regulatory, and enforcement actions as outlined in the DFS recovery plan (USFWS 1993) and the previous 5-year review (USFWS 2007).

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U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW
for
Delmarva Peninsula fox squirrel *(Sciurus niger cinereus)*

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

_____ Downlist to Threatened
_____ Uplist to Endangered
__X__ Delist
_____ No change needed

Appropriate Listing/Reclassification Priority Number, if applicable:

Review Conducted By: Chesapeake Bay Field Office

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve [signature] Date 9/28/11

REGIONAL OFFICE APPROVAL:

~~Lead~~ Assistant Regional Director, Fish and Wildlife Service

Approve Paul R. P[signature] Date 9/4/12

Appendix A. Glossary and Determination of Dispersal Distance

Dispersal Distance: A distance within which populations are considered connected. DFS populations are considered isolated from each other if they are more than 2.25 (3.6 km) apart.

Determination of Dispersal Distance: To conduct the population viability analysis (PVA) and metapopulation analysis for DFS (Hilderbrand *et al.* 2007), it was necessary to estimate a dispersal distance. This was done by applying the method outlined in Bowman *et al.* (2002) to determine maximum distance of dispersal based on home range size. The U.S. Fish and Wildlife Service recognizes 16.2 ha (40 ac) as the average home range of DFS (average of values provided by Flyger and Smith 1980, Larson 1990, Paglione 1996, Pednault-Willet 2002), resulting in a maximum dispersal distance of 18 km.

Animal dispersal can be approximated using an exponential decay function. This is typical of many mammals and supported by capture and recapture data of DFS (Larson 1990; Dueser 1999; C. Bocetti and H. Pattee, Patuxent Wildlife Research Center, in litt.). Assuming that only a very small percentage (0.1 percent) of squirrels would disperse the maximum distance of 18 km, we can then calculate the distance for a given connectance (or the reverse) by solving the equation D = lnC/-0.384, where D = distance and C = connectance.

C(0.75) = 0.75 km   C(0.5) = 1.8 km   C(0.25) = 3.6 km   C(0.10) = 6 km

Based on the negative exponential curve, only 25 percent of dispersers (connectance = 0.25) would move more than 2.25 mi from their home patch. Thus 75 percent could disperse to areas within 3.6 km, and populations in polygons that were within 3.6 km of another polygon were considered to be connected and not isolated populations.

Minimum size of a secure population: The PVA suggested that a population with 65 females, or 130 total animals, has a less than 5 percent chance of extinction in 100 years. Using an average density of DFS of 0.3 DFS per ac, it would take about 435 ac to support this number of DFS. We thus estimated that 435 ac of occupied habitat would support a minimally secure population.

Occupied Forest: Forested areas considered to be occupied by DFS. Occupied forest is delineated by the forested area that is contiguous, or adjacent to, one or several observations of DFS, and stops at any break in the forest caused by fields or roads. DFS are not considered to occur uniformly throughout the forest, but are expected to occur in some parts of the forest. These areas are delineated as polygons in the CBFO GIS. Imagery used to identify forest tracts or woodlands was originally infra-red Digital Ortho-photo Quarter Quads (DOQQ's) from the mid 1990s. Subsequently, these polygons have been drawn using the most recent color imagery from the NAPP program, currently 2007 imagery.

The first set of occupied forest polygons were originally drawn on paper maps by the Maryland DNR during the 1990s and subsequently digitized and provided to the USFWS in 1998 for use in the GIS. Additional observations of DFS, trapping reports, and other information have been recorded in the CBFO

GIS since 1998, and polygons are drawn around the adjacent forested habitat using the parameters described above.

Range: The area of land where DFS are likely to occur, delineated as the area within 3 mi of all DFS occupied forest (see Figure 1). This represents a best estimate of where DFS are likely to occur based on information about DFS occurrence and dispersal (USFWS memo dated October 8, 2004), but it does not necessarily imply that all DFS within the delineated area are interbreeding.

> **Core Area of the Range:** the area where DFS have always occurred and does not include translocations. The polygon that delineates this area is in Figure 2 of the 1993 Recovery Plan (USFWS 1993) and is shown in pink in Figure 1 of this document. This area is also called the **Natural Range** in the 1993 Recovery Plan.
>
> **Periphery of the Range:** the newly occupied portions of the historical range where DFS have either been reintroduced through translocations, or where new populations have been discovered, either because DFS have expanded back into these areas, or they have now been detected.

Rangewide population: the entire population of DFSs across its entire range.

Recovery: The principal purpose of the ESA is to return listed species to a point at which protection under the ESA is no longer required. A species may be delisted on the basis of recovery only if the best scientific and commercial data available indicate that it no longer meets the definitions of endangered or threatened.

> **Endangered species:** Any species which is in danger of extinction throughout all or a significant portion of its range (50 CFR 424.02).
>
> **Threatened species:** Any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range (50 CFR 424.02).

Subpopulations: A set of occupied habitat polygons that are located within 2.25 mi of each other and, based on the dispersal distance identified in the PVA, are considered to be close enough that individuals are likely to be interbreeding. Subpopulations are delineated by buffering the polygons of occupied habitat by 1.125 mi, and any areas that are interconnected are considered to be part of the same subpopulation (because an individual DFS would have to travel 2.25 mi or less to get from the edge of one occupied woodland to the next). Subpopulations are further delineated by rivers or peninsulas that pose geographic barriers to dispersal. Thus a subpopulation is an area of occupied forests that contain DFS that are likely to be interbreeding and are separated from other subpopulations by more than 2.25 mi. The use of subpopulations in this document is generally a way to understand if there are smaller, more isolated groups of interbreeding animals where extinction risk could be higher because of the groups' smaller size and separation from other groups of animals.

Population - The 1993 Recovery Plan uses the term population to generally describe the same thing as a subpopulation, meaning, a group of occupied forest blocks that are somewhat separated from other such groups. This document may also use the term population when referring to these same areas.

Colony – The 1993 Recovery Plan also uses the term colony to describe a new group of animals that are somewhat separated from the main distribution and occur through translocations or discovery of new groups of animals or populations. It uses the term colony in Recovery Criterion 3 and 4. This term is generally the same as a population.

Appendix B. Differences between Delmarva fox squirrels and gray squirrels

Delmarva fox squirrels have a wider tail, are more uniformly gray and have little to no brown fur.

Photos by Richard Webster/USFWS

Appendix C. Data Sources for GIS Layers and Analysis

Data Sources for Protected Lands

Federal Lands - USFWS National Cadastre data for NWR boundaries (www.fws.gov/GIS/data/cadastralDB/index.htm); data from October 2005.

Maryland State Lands - Download from http://dnrweb.dnr.state.md.us/gis/data/index.html; data from October 2008.

County Lands -Download from http://dnrweb.dnr.state.md.us/gis/data/index.html; data from September 2006.

MET/ESLC Easements - http://dnrweb.dnr.state.md.us/gis/data/index.html; data from September 2009

TNC Lands - Obtained from TNC directly; data from November 2009.

Other Private Conservation - Download from http://dnrweb.dnr.state.md.us/gis/data/index.html; data from June 2008..

Agricultural Easements - Download from http://dnrweb.dnr.state.md.us/gis/data/index.html; data from October 2005.

Rural Legacy Lands - Obtained from Rural Legacy program directly; data from November 2009.

Land Area for each County - Maryland Office of Planning, September 2005 (www.mpd.state.md.us).

Delaware State, County, Private Conservation - Obtained from Delaware Department of Natural Resources and Environmental Control, January 2005.

Data Sources for DFS Occupied Forest and Threats Analysis

Photo-imagery for background – NAPP digital imagery for each county. Most imagery is from 2007.

Occupied Forest - Polygons delineating contiguous forest around or adjacent to sightings of DFS, stopping at roads or breaks in the forest. Based on forest cover in photo-imagery described above.

Areas of anticipated development - This layer of likely development is defined in Maryland by the areas that counties have delineated for "smart growth" and that receive priority funding for infrastructure from the State (see www.mdp.state.md.us/fundingact.htm for information, and http://www.mdp.state.md.us/zip_downloads_accept.htm for data). In addition, we obtained the areas where development was already proposed from the Planning and Zoning Offices of Queen Anne's, Talbot, Dorchester, and Sussex counties and the City of Cambridge. The Maryland Office of Planning conducted the analysis of DFS occupied forest that overlapped the projected development depicted in their 2030 projections in the document "A Shore for the Future" (Maryland Office of Planning 2008).

Appendix D. State or Federal Land Protection Programs and Regulatory Programs

The following statutes, regulations, policies, and programs comprise the most relevant regulatory protections for DFS and/or their habitat.

Maryland Critical Areas Act of 1984 – This law designates all areas within 1,000 ft of high tide as Critical Areas and originally prohibited clearing within a 100-ft buffer around streams and the Chesapeake Bay. This law was amended in spring of 2008 to increase this "no-development buffer" to 200 ft. These areas serve as corridors for DFS and also breeding habitat. In addition, timber harvests that occur within designated Critical Areas must be reviewed by the State if sensitive or endangered species are present. Where DFS occur, 15 to 25 percent of each forest stand must be retained, consistent with recommendations in the 1993 recovery plan. The area selected for retention is based on maintaining both the best DFS habitat and connectivity to other tracts of forest. Review of timber harvest plans and habitat retention will not necessarily occur after delisting. The proportion of each county that lies within the Critical Area varies but is highest in Dorchester County, where 50 percent of the land is designated; Talbot County is second highest, with 38 percent.

Maryland Forest Conservation Act of 1991 – This law requires that when a forested area is cleared and converted to other land use, other portions of the forest must be placed in an easement that will preclude development in perpetuity. The total acreage in Forest Conservation easements has not yet been tabulated but generally includes forested areas near housing developments for which forested areas were initially cleared. This leads to protection of habitat for DFS to move into or move through in urbanizing areas.

Maryland Agricultural Land Protection Program – Established in 1977, the Maryland Agricultural Land Preservation Foundation (MALPF was created to preserve farmland and woodland for the continued production of food and fiber. This program has conserved over 75,000 ac in the eight-county area. In the tri-county area, MALPF easements have been established at a rate of 1,353 ac per year. Most of these easements are whole farm easements, which are primarily agricultural fields but also include wooded areas. Protections through this program maintain forest/agricultural edges for the DFS.

Maryland Environmental Trust – Established in 1967, the Maryland Environmental Trust (MET) is a State organization that holds conservation easements on private lands. MET easements in the tricounty area (Dorchester, Talbot and Queen Anne's) were acquired at an estimated rate of 1,130 ac per year from 1990 to 2000. The Eastern Shore Land Conservancy (ESLC) has obtained easements on 21,359 ac (many co-held with MET) since 1990 in the eight Maryland counties where DFS occurs, and in the year 2000 a total of 4,149 ac of farmland and natural habitat were protected (ESLC, spring 2001 newsletter).

Maryland Rural Legacy – Established in 1997, the Rural Legacy Program was created to protect large, contiguous tracts of Maryland's most precious cultural and natural resource by purchasing easements that protect property from future development. There are targeted areas that are the focus of this work; for example, Talbot County has identified the Tuckahoe riparian corridor for its Rural Legacy area, which will help preserve an important north/south corridor for DFS. Queen Anne's County has preserved lands in northern part of the county (Chino Farms), which includes the northernmost observation of DFS. Dorchester County has identified an area in the northeast portion of the county that is not currently occupied by DFS but represents an upland area not vulnerable to sea level rise.

Maryland Program Open Space – Established in 1969, Program Open Space Funds are allocated, in part, to purchase land for state parks, forests, wildlife habitat, natural, scenic and cultural resources for public use. Stateside POS projects are now being driven by a new Targeting System, which uses the best scientific information available to target the program's limited funds. (http://www.dnr.state.md.us/land/landconservation.asp)

Maryland Smart Growth/Rural Legacy – This program, established in 1997, attempts to offset sprawl by identifying Smart Growth areas in each county where the State of Maryland will fund infrastructure projects such as sewers and roads. The program also identifies Rural Legacy areas where land protection focuses on preserving rural and natural resources (see Land Protection Programs below).

Maryland Greenprint Program – This program is aimed at preserving corridors and hubs (large patches) of undeveloped habitat across the State. Beginning as a study of forest land connectivity under the rubric of the Green Infrastructure Project, the Greenprint program is focused on coordinating Rural Legacy and county open space protection efforts with a view to preserving this Green Infrastructure.

Delaware Biodiversity Conservation Partnership – This State program was developed with input from stakeholders, scientists, state and federal resource management agencies, and nongovernmental groups (Environmental Law Institute 1999, Delaware Department of Natural Resources and Environmental Control 2001). The Biodiversity Conservation Partnership focuses on identifying priority actions in four areas: science, resource management, land use planning, and education and outreach. Recovery of DFS (e.g., habitat protection in the Nanticoke River watershed) could be advanced through this initiative.

Delaware Farmland Preservation Program – Established in 1991, this program preserves working farms but can include working forests and typically includes a "Purchase of Development Rights." Several private land trusts are also active. The State also participates in the Forest Legacy Program, which prevents development and encourages wise stewardship of timber resources. Maps of State Resource Areas (SRAs) provide information that can be used by counties or other entities in planning conservation areas. Delaware's Landowner Incentive Program encourages (through financial and technical assistance) landowners to manage property for rare species, especially listed species.

Federal Wetland Reserve Program – Established by the 1990 Farm Bill, the "Wetlands Reserve Program (WRP) provides payments and cost sharing to farmers in exchange for restoring farmed wetlands. WRP can compensate farmers for placing restored wetlands either in permanent or in 30-year easements, and can provide cost share assistance for restoration work. Land is eligible for WRP if it is farmed wetland or converted wetland (along with adjacent lands that are functionally dependent upon that particular wetland), so long as it was converted before enactment of the 1985 Farm Bill. Riparian areas that link wetlands protected by easements are also eligible." (http://www.ibiblio.org/farming-connection/farmpoli/features/makesens/wrp.htm).

Federal The Clean Water Act – Established in 1927, Section 404 of the Clean Water Act protects wetlands from destruction and this includes forested wetlands which provide habitat for DFS. This Act is often implemented by the States but it requires that destruction of wetlands be avoided, minimized and mitigated. This protection of forested wetlands has been a major factor in protection of DFS habitat in the past. These protections will continue into the future, even after delisting.

State Lands

Maryland manages several State-owned properties that currently support DFS or provide habitat for possible expansion of the population. These include State Wildlife Management Areas, State Forests, and Chesapeake lands. DFS are currently supported on approximately 6,800 ac of state Wildlife Management areas, including Wye Island, LeCompt, Linkwood, Fishing Bay, Seth Demonstration Forest, and Taylor's Island in Maryland. In addition, the State of Maryland has acquired 58,000 ac of forest land previously owned by the Chesapeake Pulp Wood Company. Management plans for these Chesapeake lands already have specific goals for DFS and provides an example for other State Forest lands. Long-term management plans are not currently available for all State properties, but additional plans with a focus on DFS may result from current Habitat Conservation Plan work. General goals and missions of these lands support the conservation of Maryland wildlife, and one WMA was specifically set aside for the DFS. These properties will likely include management for DFS even after this species is delisted.

Delaware manages both State Wildlife Management Areas and State Forests that either currently support DFS or could in the future. Delaware's Land Protection Act provides for acquisition of interests or rights in real property for State Open Space areas. In addition, several accounts exist to purchase land and conservation easements for open space, waterfowl habitat, state parks, and other state land. Legislation was approved in 1995 transferring approximately $6 million from other accounts to fund greenway projects and other land acquisitions, and approximately $7 million per year is available for acquisition of state land from state bond funds. With regard to conservation on private lands, conservation and preservation easements are provided for by statute, and a Natural Areas Preservation system encourages private landowners to set aside land for wildlife habitat.

Virginia has a policy to manage the State's wildlife resources "to maintain optimum populations of all species to serve the needs of the Commonwealth." The Virginia Department of Game and Inland Fisheries (VDGIF) is the Commonwealth's wildlife and freshwater fish management agency and exercises full law enforcement and regulatory jurisdiction over those resources, inclusive of State or federally endangered or threatened species, but excluding listed insects. A new statute amending Virginia's Endangered Species Act was passed in 2011 that enables the VDGIF to designate a population of a State-listed species (species that are also federally listed will be excluded from this provision) as "experimental," through appropriate regulatory channels, that would allow for the deliberate introduction of the species into currently unoccupied areas for the purpose of enhancing the long-term survival of the species or population. Any regulation designating an experimental population shall require a conservation plan specific to the population under consideration, specify the circumstances under which taking of an individual member of an experimental population will be exempt from the prohibitions and penalties authorized under the State Endangered Species Act, and describe the geographic extent of the experimental population, which shall be distinct from naturally occurring populations continuing to be subject to the prohibitions and penalties authorized under the State Endangered Species Act. Should the DFS be removed from the Federal endangered species list, this statute will offer Virginia additional latitude for future DFS reintroductions.

Virginia has habitat acquisition programs such as the Conservation and Recreation Fund, which is used to purchase land for several purposes including wildlife habitat and natural areas, and bonds have been approved for acquisition of state park lands and state natural area preserves. Virginia also has some private land conservation programs. For example, under the Natural Area Preserve Act, private lands can be registered as a natural area. Conservation easements are authorized by statute, with land subject to the easement exempt from state and local taxation. The Forest Stewardship Program works with private landowners to address concerns, and by law, owners can convert agricultural land to wildlife management uses without losing their property tax exemption. Finally, the Coverts Project works with private landowners on biodiversity, ecosystem, and wildlife management theories and techniques.

Federal Lands

The DFS occurs on three National Wildlife Refuges, Chesapeake Marshlands Complex which includes Blackwater, Chincoteague and Prime Hook. The DFS is a focus of the management plans for these Refuges, and management for this species is included in their Comprehensive Conservation Plans. These Refuges will continue to provide protected habitat for the DFS after delisting. Future acquisitions for these refuges may also benefit the DFS.

Appendix E. Development of LiDAR Map of Forest Height to Identify DFS Habitat

Objective: The objective of this analysis was the production of a map of Dorchester County forests using forest height classes. This data enabled identification and an inventory of mature forest that provide potential Delmarva fox squirrel habitat. This data also has uses for other wildlife applications and for forestry. The analysis has now been completed for the eight Maryland Counties where Delmarva fox squirrels occur.

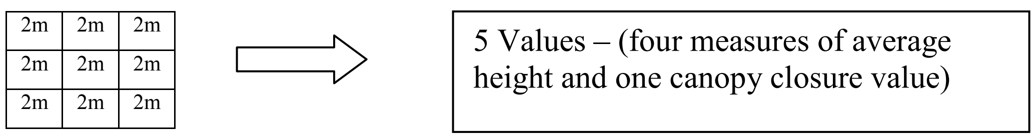
Introduction: The Delmarva fox squirrel prefers mature stands of mixed pine/hardwood forest (Dueser *et al.*1988, Dueser 2000, Morris 2006). Traditionally, habitat models for this species have used the dbh of trees to reflect forest maturity (Dueser 1988, 2000). Existing remote sensing data and maps delineated forest by dominant tree species but did not distinguish forest maturity, thus a wide spread inventory of DFS habitat was not possible. However, forest height is clearly different between the basic age classes of forest such as mature forest, pole timber and young regenerating stands and tree height can be a significant predictor of where DFS occur in a forest (Morris 2006). Airborn Lidar (Light Detection and Ranging) laser data measures forest canopy height and initial work in Delaware found LiDAR could discern suitable habitat for the DFS (Nelson 2003).

Lidar data was available for the State of Maryland and had been used to create a detailed elevation map. But the "first return" data, i.e. the first bounce of the laser off of the forest canopy, had not been analyzed. Staff of the Chesapeake Bay Field Office collaborated with partners from Goddard Space Center and the Maryland Department of Natural Resources to work with a contractor to analyze this information and produce a map of forest canopy height and canopy closure.

The final product is a map of Dorchester County forests showing six height classes and identification of the height classes expected to be suitable for Delmarva fox squirrels (Boss 2007). This LiDAR model of Delmarva fox squirrel habitat was evaluated by comparison to the presence or absence of DFS at camera locations at Blackwater National Wildlife Refuge (Morris 2006). There was significantly more LiDAR defined DFS habitat associated with locations where DFS were "captured" by cameras. Thus, the LiDAR defined habitat model appears to be a useful assessment of potentially suitable habitat.

I. Development of the Map:

LiDAR data was obtained from the MD DNR. LiDAR data measures the elevation of the "first-return" of the laser data as it bounces of the forest canopy and also measures the "last-return" or ground elevation. The difference between these two measurements is a measure of canopy height. The laser data is a stream of points "shot" back and forth as the plan flies across the landscape. Data were collected at 2-m grids but grouped to the 6 m grid size. The density of points averaged about 23 points in a 6-m x 6 m grid cell. From these an average canopy height is calculated for the 6m grid cell. At each 6 m grid, four measures of average height and one measure of canopy closure were calculated, but the quadratic mean height for each grid cell was used to develop the model (Boss 2007). Note that LiDAR defined canopy height is not the same as a canopy height measured from the ground by a forester. LiDAR defined canopy height is taking the average height of a rolling canopy layer with many high and low parts to the canopy. While a forester on the ground is typically picking one of the tallest trees and measuring that height.



The grid cell heights and canopy closures were first grouped into 11 habitat types but this was then further combined into the six main habitat types described below (Figure 1). Based on previous work, (Dueser 2000, Nelson *et al.* 2005, and Morris 2006) we estimated that DFS habitat was comprised of forest stands primarily in habitat class 1 and 3, the tallest forest stands. We further estimated that DFS may use habitat class 5 only if, there was at least 20% of habitat class 1 and 3 in the polygon. This estimated description of DFS habitat was informed by previous work but also was examined in test plots to evaluate whether this effectively described where we knew DFS occurred and did not occur on the test plots.

Figure 1. Six habitat classes based on canopy height (QMHC- quadratic mean height of canopy) and canopy closure. Habitat classes are indicated by color and Y indicates that yes, it is considered to be DFS habitat; N indicates no, it is not considered to be DFS habitat. Habitat Class 5 is DFS habitat, only if it is associated with at least 20% of forest types taller than that.

	Canopy Closure				
	80-100%	**60-80%**	**30-60%**	**10-30%**	**0-10%**
LiDAR Canopy Height	5	4	3	2	1
(meters)					
Height Class 1 > 20 m (>66 ft)	**1 -Y**				
Height Class 3 16-20 m (54-65 ft)	**3-Y**				
Height Class 5 13-16 m (43-53 ft)	**5-Y(if with > 20%1,3)**				
Height Class 7 7-13 m (21-42 ft)	**7-N**				
Height Class 8 3 - 7m (10-20 ft)	**8-N**				
Height Class 9 <3m (<10 ft)	**9 -N**				

Figure 2. Six LiDAR forest height classes in an example scene from Dorchester County.

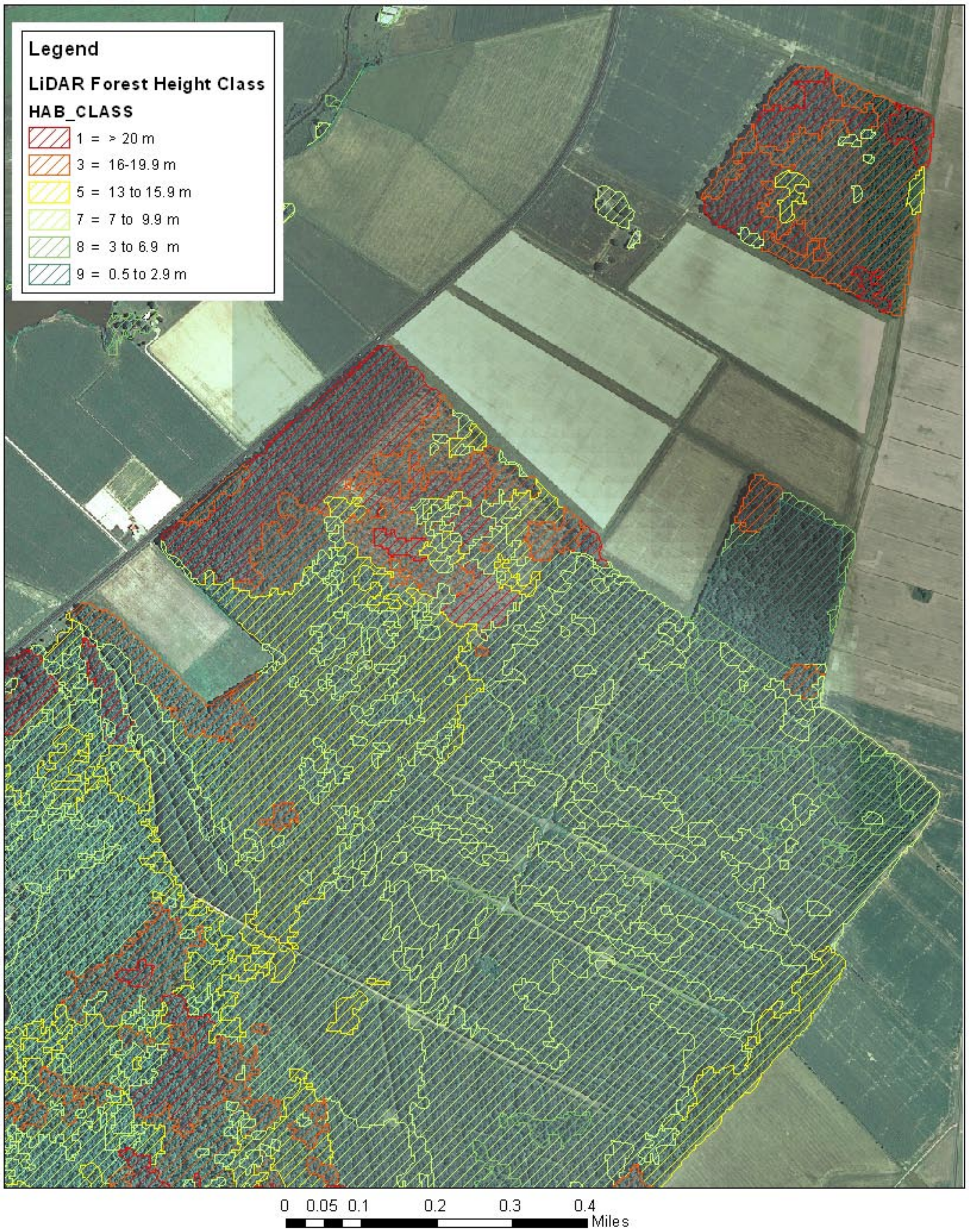
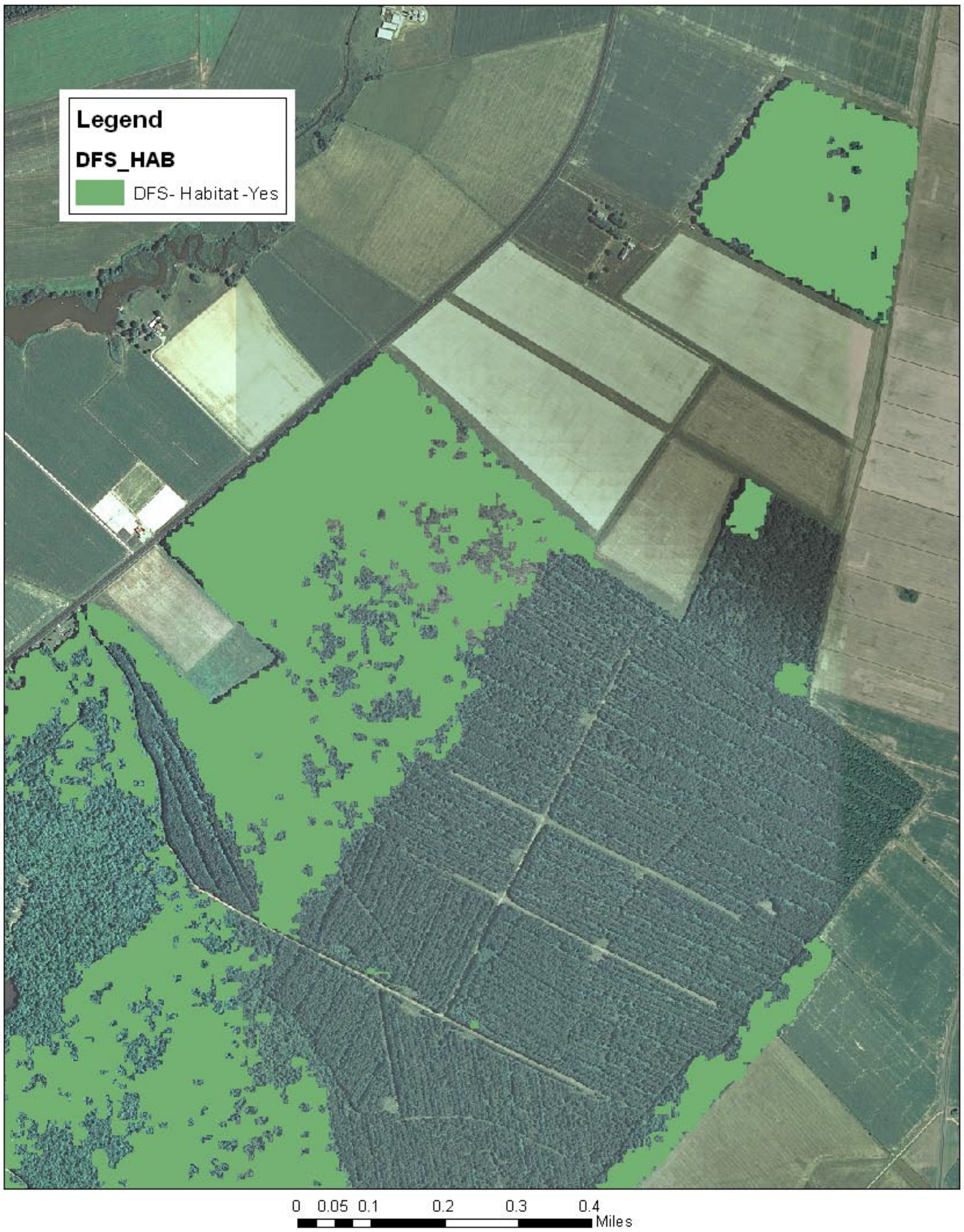
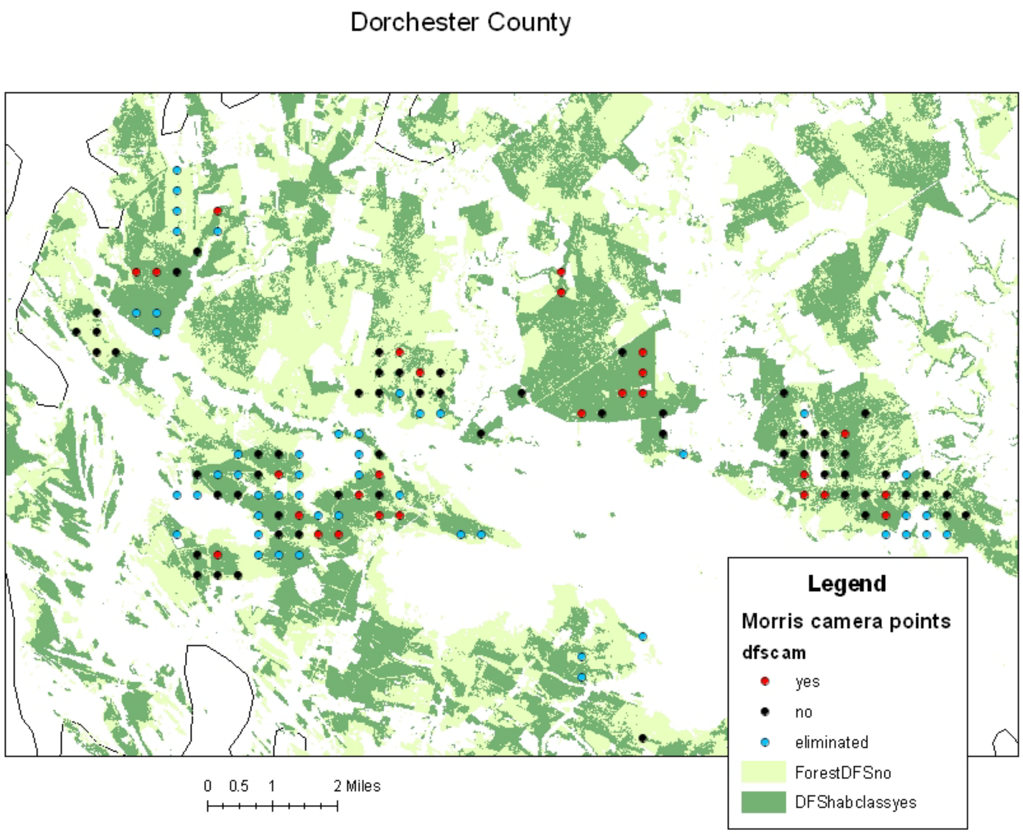


Figure 3. DFS habitat according to the LiDAR model developed from the height classes in the same example scene from Dorchester County



II. Testing the Lidar Model: Subsequently, we evaluated this LiDAR Habitat Model for DFS by considering the LiDAR defined habitat surrounding points where DFS had been determined present versus absent at monitoring points at Blackwater NWR (Morris 2006). We compared the acres of LiDAR defined DFS habitat in the 40 acres surrounding points where DFS were "captured" on film and compared this to the acres of LiDAR defined DFS habitat in the 40 acres surrounding points where DFS were *not* captured on film. Note: 40 acres is considered the average size of a DFS home range.



Results: At the 27 points where DFS were detected, there was a mean of 29.2 acres (73%) of LiDAR defined habitat in the surrounding 40 acres. In the 58 points where DFS were not detected by the cameras, there was a mean of 21.4 acres (54%) LiDAR defined habitat in the surrounding 40 acres. These means were significantly different ($P<0.002$, t-test). Thus the points where DFS were detected had significantly more LiDAR-defined DFS habitat than points where DFS were not present. While further testing of this LiDAR habitat model would be desirable, based on existing information, we conclude that the LiDAR habitat model is a reasonable expression of DFS habitat, and at the very least, describes the more mature forest that is likely to be suitable for DFS. It is a suitable screening tool for mature forest that has the potential to be suitable for DFS.

III. Evaluating forest age or maturity of the LiDAR canopy height classes using Chesapeake Lands.

To confirm that LiDAR forest canopy height was related to forest maturity, we examined the LiDAR on Chesapeake Lands currently owned by the MD DNR. Chesapeake Forest Products Corporation ("Chesapeake") had been the major industry on the Delmarva Peninsula managing for short-rotation pine. In 1999, the State of Maryland acquired 58,000 acres of Chesapeake land to be managed for sustainable sawtimber production and wildlife values. These lands comprise scattered parcels throughout the southern four counties. There are 11,527 acres of Chesapeake lands in Dorchester County. Because of their past as forest industry lands, and the State's recent acquisition, there is good information on the harvest history of these lands and thus the age of the stand at the time the LiDAR data was collected (2003).

Methods: Using the CBFO GIS, we determined the stand age and LiDAR habitat class map for 306 stands ≥ 5 acres in size from the Chesapeake lands in Dorchester County. The LiDAR data is fairly detailed, so we only used polygons ≥ 5 acres in size to obtain polygons that were likely to have resulted from a harvest. Smaller polygons were often small leave areas or sites associated with smaller topographic differences.

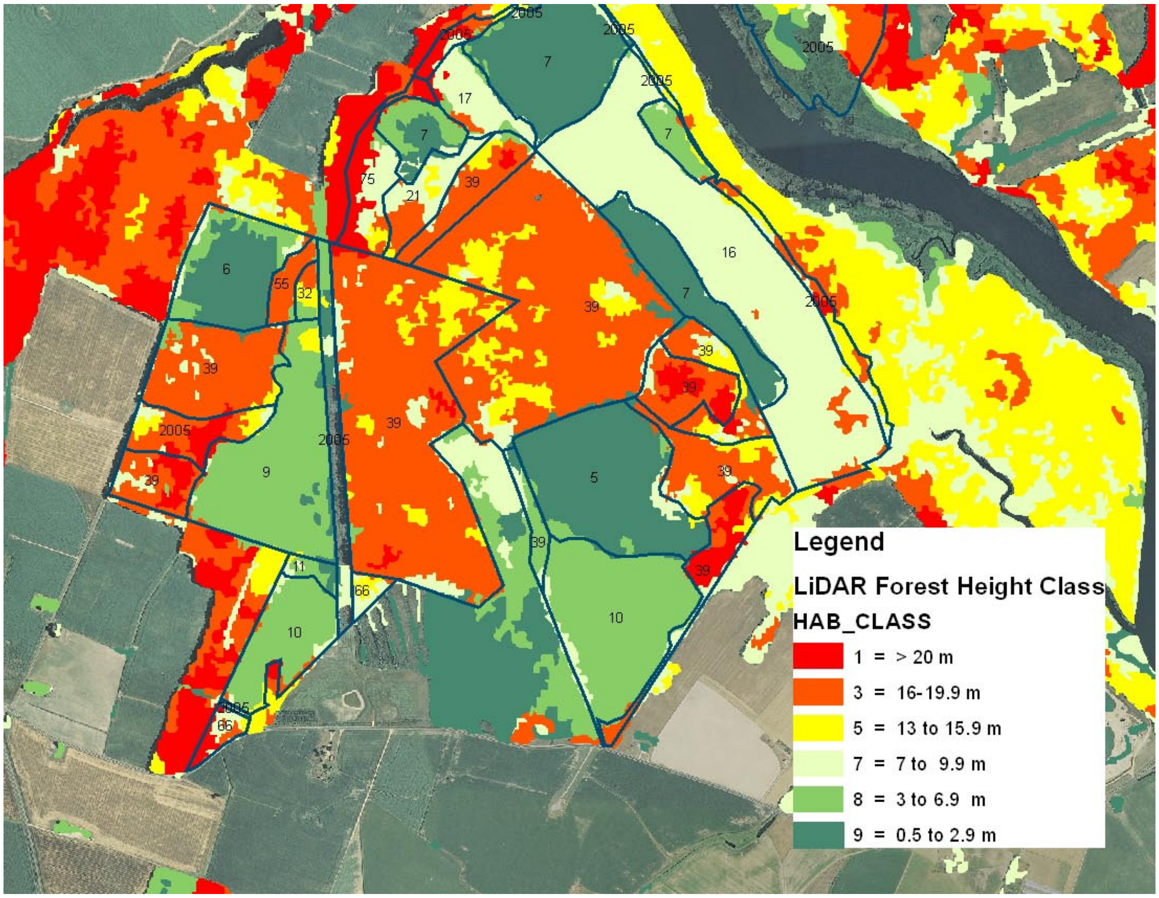
Results: The mean age of the shortest habitat class (1-10 feet tall) is about 5 years old, based on 14 stands (Table 1). Stands in height class 7 (21-42 feet tall) are typically 24 years old based on 109 stands in this height class. Stands in the tallest height class averaged about 66 years old. The forest canopy height identified by LiDAR does reflect the age of the stand in the Chesapeake lands (Table 1). Again, note that LiDAR defined canopy height is not the same as a canopy height measured from the ground by a forester. LiDAR defined canopy height is taking the average height of a rolling canopy layer with many high and low parts to the canopy. Thus, the LiDAR defined canopy height will be lower than what a forester might measure from the ground.

In Table 1 we have also included an approximate forest stage description for each habitat class (seedling/sapling, sapling/poletimber, etc.) These are not based on the dbh of trees as would normally be used by a forester classifying the stand in the field, but are rather approximate stages based on ages of these habitat classes and discussion with local foresters.

Table 1. Mean age of each LiDAR Height Class from 360 stands of known age on Chesapeake Forest Lands in Dorchester County. Lower and upper bracet of age class based on the lower and upper C. I. for the age class and if overlapped, divided equally to provide separate age classes.

LiDAR Canopy Height Class	**LiDAR canopy height (meters and feet)**		***n***	***Mean age (years)***	***Lower***	***Upper***
1	> 20 m	(>66 ft)	14	**66**	61	75
3	16-20 m	(54-65 ft)	43	**49**	46	60
5	13-16 m	(43-53 ft)	68	**40**	32	45
7	7-13 m	(21-42 ft)	109	**24**	13	31
8	3 - 7 m	(10-20 ft)	58	**9**	7	12
9	<3m	(<10 ft)	14	**5**	1	6

Figure 4. Example of ages of Chesapeake Forest stands and LiDAR height classes.



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List of Tables and Figures

Figure 10. Connectivity of DFS subpopulations to 175-hectare forest patches using jwalk model.

Figure 11. DFS distribution in relation to future development in smart growth areas in Maryland or municipalities in Delaware.

Figure 12. Land remaining after a 2-foot inundation (in Maryland) and DFS occupied forest lost through inundation and isolation. Arrows indicate areas where DFS are expected to move inland over time.

Figure 13. Location of DNR owned Chesapeake forest lands.

Table 1. Summary of the success of sixteen translocations of Delmarva fox squirrel populations.

State	County	NAME (Successful translocations in Bold)	Release Year(s) and number of DFS released including supplements	Successful?	Evidence of growth or expansion beyond release site	Documentation - Citation of most recent monitoring report or data.
MD	Kent	**Andelot Farm**	1991 (21 dfs)	**YES**	YES	Therres and Willey 2002: sightings 2003-2009; trap and camera surveys 2009-2011.
MD	Kent	**Remington / Chesapeake Farms**	1979-1980 (14 dfs); 1980-1983 (5 dfs); Supplement 1994 (25 dfs)	**YES**	YES	Therres and Willey 2002: sightings 2003-2009; trap and camera surveys 2009-2011.
MD	Kent	**Quaker Neck**	1980,1981 (16 dfs); Supplement 2000 (18 dfs).	**YES**	YES	Therres and Willey 2002: sightings 2003-2009; trap and camera surveys 2009-2011.
MD	Caroline	**Harmony**	1989 (30 dfs)	**YES**	YES	Therres and Willey 2002: sightings 2003-2009; trap and camera surveys 2009-2011.
MD	Wicomico	**Hazel Farm**	1986-1988 (20 dfs); Supplement 1999 (11 dfs)	**YES**	YES	Therres and Willey 2002: sightings 2003-2009; trap and camera surveys 2009-2011.
MD	Somerset	**Riggin Farm**	1983-1985 (26 dfs); Supplement 2000 (9 dfs)	**YES**	YES	Therres and Willey 2002: sightings 2003-2009; trap and camera surveys 2009-2011.
MD	Somerset	**Eby Farm**	1981 (9 dfs); Supplement 1993 (17 dfs)	**YES**	YES	Therres and Willey 2002: sightings 2003-2009; trap and camera surveys 2009-2011.
MD	Somerset	**Dryden Farm**	1981 (9 dfs); Supplement 1999 (19 dfs)	**YES**	YES	Therres and Willey 2002: sightings 2003-2009; trap and camera surveys 2009-2011.
MD	Worcester	**Jarvis Farm**	1982-1984 (8 dfs); Supplement 1997 (21 dfs); 1 mile NE	**YES**	YES	Therres and Willey 2002: sightings 2003-2009; trap and camera surveys 2009-2011.
VA	Accomack	**Chincoteague**	1968-1971 (34 dfs)	**YES**	YES	Pednault-Willett 2002; refuge trapping report 2010.
DE	Sussex	**Prime Hook NWR**	1986,1987 (17 dfs)	**YES**	YES	2004 State Survey at PHNWR; sightings 2005-2009. Results of camera surveys 2011.
DE	Sussex	Assawoman	1984-1985 (13 dfs)	NO		2004 State Survey at Assawoman Wildlife Area.
VA	Northampton	Brownsville Farm	1982-1983 (24 dfs)	NO		Report to State, Terwilliger 2000
PA	Chester	Chester	1987-1988 (20 dfs)	NO		Report by M.Steele, 13 June 1996
MD	Cecil	Fairhill	1980-1982 (14 dfs)	NO		Therres and Willey 2002.
MD	Worcester	Nassawango	1978 (5 dfs)	NO		Therres and Willey 2002.

Table 2. Land use area in the nine Maryland and Delaware counties where Delmarva fox squirrels occur: 2002

County	Developed (acres)	Agriculture (acres)	Wetlands (acres)	Forest (acres)	Total Land (acres)
MARYLAND (a)					
Kent	10,794	118,451	4,399	44,735	178,440
% of County	**6**	**66**	**2**	**25**	
Queen Anne's	20,532	150,080	3,840	63,068	237,549
% of County	**9**	**63**	**2**	**27**	
Talbot	22,106	103,518	4,500	41,444	171,622
% of County	**13**	**60**	**3**	**24**	
Caroline	16,388	121,347	3,204	63,710	204,743
% of County	**8**	**59**	**2**	**31**	
Total for northern Counties	69,820	493,396	15,943	212,957	792,354
	9	**62**	**2**	**27**	**100**
Dorchester	17,307	119,824	91,019	126,760	355,142
% of County	**5**	**34**	**26**	**36**	
Somerset	12,169	56,077	56,027	82,518	206,931
% of County	**6**	**27**	**27**	**40**	
Wicomico	34,287	85,403	14,385	106,236	240,404
% of County	**14**	**36**	**6**	**44**	
Worcester	21,558	98,822	18,858	159,988	301,650
% of County	**7**	**33**	**6**	**53**	
Total for southern Counties	85,321	360,126	180,289	475,502	1,104,127
	8	**33**	**16**	**43**	
All Eight MD Counties	155,141	853,522	196,232	688,459	1,896,481
	8	**45**	**10**	**36**	
DELAWARE (b)					
Sussex DE	30,211	324,434	20,541	208,560	601,456
% of County	**5**	**54**	**3**	**35**	
Total Nine County Area	185,352	1,177,956	216,773	897,019	6,290,999
% of all Nine Counties	**7**	**47**	**9**	**36**	

Source : (a) Maryland Office of Planning, September, 2005.(www.mpd.state.md.us) *Development = total of all low, medium and high density residential, and commercial, industrial, institutional and other developed land.*(b) RECON Jan 19, 2006

Table 3. Acres of land protected from development in the eight Maryland Counties and Sussex County Delaware.

	Queen Anne's	Talbot	Dorchester	Kent	Caroline	Wicomico	Somerset	Worcester	Sussex	Total
Federal Ownership	145	0	25,778	2,103			4,293	10,127	10,084	52,530
State Ownership	4,791	244	31,294	4,958	6,077	6,094	30,389	20,781	41,508	146,136
State (Chesapeake Lands)	0	0	11,527	0	1,231	15,866	17,088	12,843	N/A	58,555
POS State and local acquisitions	2,483	1,879	6,037	1,123	279	25,995	1,460	3,769	N/A	43,025
MET easements	8,126	12,099	12,078	10,218	4,809	1,701	4,316	5,883	N/A	59,230
MD Rural Legacy Program	4,079	1,250	6,253	1,285	2,890	1,356	0	6,884	N/A	23,996
MALPF	24,091	10,761	12,604	16,465	30,717	6,413	4,774	6,325	N/A	112,151
CREP	459	63	78	58	33	660	1,937	770	N/A	4,058
TNC and other private	1,782	2,041	4,954	3,505	1,353	3,884	1,953	4,450		23,922
Delaware Forest Legacy Program									2,032	2,032
Delaware Farmland Preservation									29,295	29,295
Total Acres Protected	45,955	28,336	110,602	39,715	47,390	61,969	66,211	71,833	82,919	554,930
Total Land Area in County	237,549	171,622	355,142	178,440	204,743	240,404	206,931	301,650	601,456	2,497,937
% of County Land Area Protected from Development	**19%**	**17%**	**31%**	**22%**	**23%**	**26%**	**32%**	**24%**	**14%**	**22%**

Table 4. Acres and percent of total forest that is mature forest potentially suitable for DFS in each Maryland county, and the acres and percentage of mature forest that is occupied by DFS. Data come from Lidar analysis for Maryland.

County	Total acres of forest from Lidar	Acres of Lidar defined Mature Forest (Potential DFS Habitat)	% of total forest that is mature	Acres of *Occupied* Mature Forest	Percentage of Mature Forest in each county (potential habitat) that is occupied by DFS
Kent	52,184	35,209	67%	2,635	**7%**
Queen Anne's	59,052	40,220	68%	3,766	**9%**
Talbot	76,237	52,167	68%	14,581	**28%**
Caroline	74,633	44,821	60%	1,488	**3%**
Dorchester	168,002	66,393	40%	45,408	**68%**
Wicomico	120,353	56,193	47%	1,414	**3%**
Worcester	138,453	98,675	71%	1,331	**1%**
Somerset	94,530	40,378	43%	1,927	**5%**
Maryland Total	783,444	434,056	55%	72,550	**17%**
Sussex DE*	226,100	136,600	60%	2,294	

* Sussex Count Delaware does not have Lidar data available and data on mature forest are from 2001 FIA estimate of proportion of timberland in sawtimber.

Table 5. Total acres of forest occupied by Delmarva fox squirrels and the acres (and percent) protected from development in each county through public ownership and easements.

	Queen Anne	Talbot	Dorchester	Caroline	Kent	Wicomico	Somerset	Worcester	Sussex DE	Accomac VA	Totals
Federal Land 2010	0	0	9,128	0	0	0	0	0	607	1,504	11,238
State owned land 2010	1,441	130	9,179	357	0	102	1,086	653	995	0	13,942
County Park 2010	20	1	74	0	0	0	0	0	0	0	95
MET 2010	896	2,502	3,319	206	949	500	6	0	0	0	8,377
TNC 2010	0	427	213	2	0	0	0	0	0	0	642
MALPF Easement 2010	152	625	1,790	78	0	0	53	0	0	0	2,698
Rural Legacy Easement 2010	716	31	827	0	0	0	0	958	0	0	2,532
Total acres of occupied forest on protected lands	3,225	3,715	24,530	642	949	602	1,144	1,611	1,602	1,504	39,524
Total acres of DFS occupied forest in each County 2010	**4,871**	**18,179**	**93,366**	**2,171**	**3,758**	**2,055**	**4,597**	**1,983**	**2,294**	**1,504**	**134,778**
Percentage of DFS occupied forest on protected land	**66%**	**20%**	**26%**	**30%**	**25%**	**29%**	**25%**	**81%**	**70%**	**100%**	**29%**

Source: CBFO GIS analysis of DFS occupied forest (see Appendix for definitions) and GIS data on protected lands available at www.MDDNR. Note: Comparisons of acreage of occupied forest between 2007 Status Review and this analysis include changes that result in some extirpation in Queen Anne County and Dorchester, newly discovered occupied forest in many counties, and editing of occupied forest polygons to better follow forest edges and stop at roads and fields.

Table 6. Comparison of timber harvest rates in each Maryland County estimated from Sediment and Erosion Control permits in two time periods. The Previous Harvest Rate was reported in the Previous Status Review, and more Recent years were obtained for the second harvest estimate.

County (years of permit records examined for previous and recent estimate of harvest rate)		Previous Annual Harvest Rate (acres/yr)	Recent Annual Harvest Rate (acres/yr)	% Change in average annual acres harvested	Average size of harvest from early time period (acres)	Average size of harvest from more recent time period (acres)	Change in average size of harvests (acres)
Kent	(1992-1999; 2005-2009)	521	308	**-41**	38	46	**8**
Queen Anne's	(2001-2005; 2006-2009)	448	729	**63**	37	48	**11**
Talbot	(2004-2005; 2009-2010)	532	172	**-68**	29	22	**-7**
Caroline	(1994-1999; 2007-2010)	845	1118	**32**	37	37	**0**
	Northern County mean	***587***	***582***				
Dorchester	(1994-2005; 2006-2009)	2507	1261	**-50**	70	47	**-23**
Wicomico	(1992-1999; 2005-2009)	2788	661	**-76**	47	27	**-20**
Worcester	(1994-2004; 2008-2010)	2232	418	**-81**	49	43	**-6**
Somerset	(1994-1999; 2005-2009)	2849	656	**-77**	49	27	**-22**
	Southern County mean	***2594***	***749***				
Sussex DE	(1998-2005; 2006-2009)	**3376**	**1806**	**-47**	38	27	**-11**

Table 7. Acres of occupied forest in the 2010 subpopulations and acres remaining after all predicted losses from development and sea-level rise by 2030, with and without expected gains from discovery. (a)

2010 Subpopulation	2010 Acres of Occupied Forest	Acres remaining in 2030 after all losses and no projected gains	Acres remaining in 2030 after all losses and expected discoveries (at rate of 944 acres/yr) (b)	Proportion of 2010 forest that is mature	2010 Starting # of MVP's	2030 # of MVP's if all losses and no gains (worst case)	2030 # of MVP's with losses and expected gains	2010 conclusion on future persistence after all projected losses and degree of isolation
Dorchester / Nanticoke*	95,725	58,398	70,204	0.481	117	71	86	**likely to persist**
Tunis and Wye Mills*	8,328	8,075	9,707	0.789	17	16	19	**likely to persist**
Southern Talbot*	7,598	6,698	8,052	0.823	16	14	17	**likely to persist**
Tuckahoe River Corridor	2,896	2,618	3,147	0.748	2	2	3	**likely to persist**
Carmichael Road*	1,706	1,623	1,951	0.809	4	3	4	**likely to persist**
St Michaels Road*	1,390	802	964	0.753	3	2	2	**likely to persist**
Remington Farms (T)	2,549	2,549	3,064	0.734	2	2	3	**likely to persist**
Eby and Dryden (T)	2,125	2,121	2,550	0.402	1	1	1	**likely to persist**
Hazel Farm (T)	2,055	2,055	2,470	0.688	2	2	2	**likely to persist**
Northern Somerset	1,916	1,880	2,260	0.373	1	1	1	**likely to persist**
Jarvis Farm (T)	1,685	1,685	2,026	0.625	1	1	1	**likely to persist**
Chincoteague (T)	1,503	0	0	0.900	2	<1	<1	**might persist (c)**
Andelot Farms (T)	916	916	1,101	0.618	1	1	1	**likely to persist**
Prime Hook (T)	902	902	1,084	0.900	1	1	1	**might persist**
Chino Farms	797	797	958	0.769	1	1	1	**might persist**
Wye Island*	577	577	694	0.670	1	1	1	**might persist**
Riggin Farm (T)	478	478	575	0.685	<1	<1	<1	**might persist**
301 and 50 Split	401	369	444	0.766	<1	<1	<1	**expected extirpation**
Hampton Woods	361	262	315	0.957	<1	<1	<1	**expected extirpation**
Quaker Neck (T)	293	293	352	0.674	<1	<1	<1	**might persist**
St Michaels South*	203	203	244	0.655	<1	<1	<1	**might persist (d)**
Somerset new 2005	92	92	110	0.534	<1	<1	<1	**might persist (d)**
Total Sum	**134,496**	**93,393**	**112,273**		**171**	**120**	**145**	

(a) MVP's were calculated based on the acres of occupied forest multiplied by the proportion of mature forest. This product was multiplied by the density of DFS in that county (either 0.33 or 0.15 dfs/acre) and the product divided by 130 animals (size of a MVP from Hilderbrand et al. 2007). **(b)** gains of 944 acres/yr for 20 yrs equals a total of 18,880 acres which was distributed proportionally by the size of the subpopulation after losses. **(c)** might persist if DFS are moved from island to new locations - we are using a very worst case scenario of complete loss from sea-level rise. **(d)** these subpopulations, while currently small, are expected to merge with other subpopulations because of their location. **(*)** MVP in these subpopulations calculated using density of 0.33 dfs/acre; 0.15 dfs/acre used in all other subpopulations.

Figure 1. Recent changes in the range of the Delmarva fox squirrel (DFS).

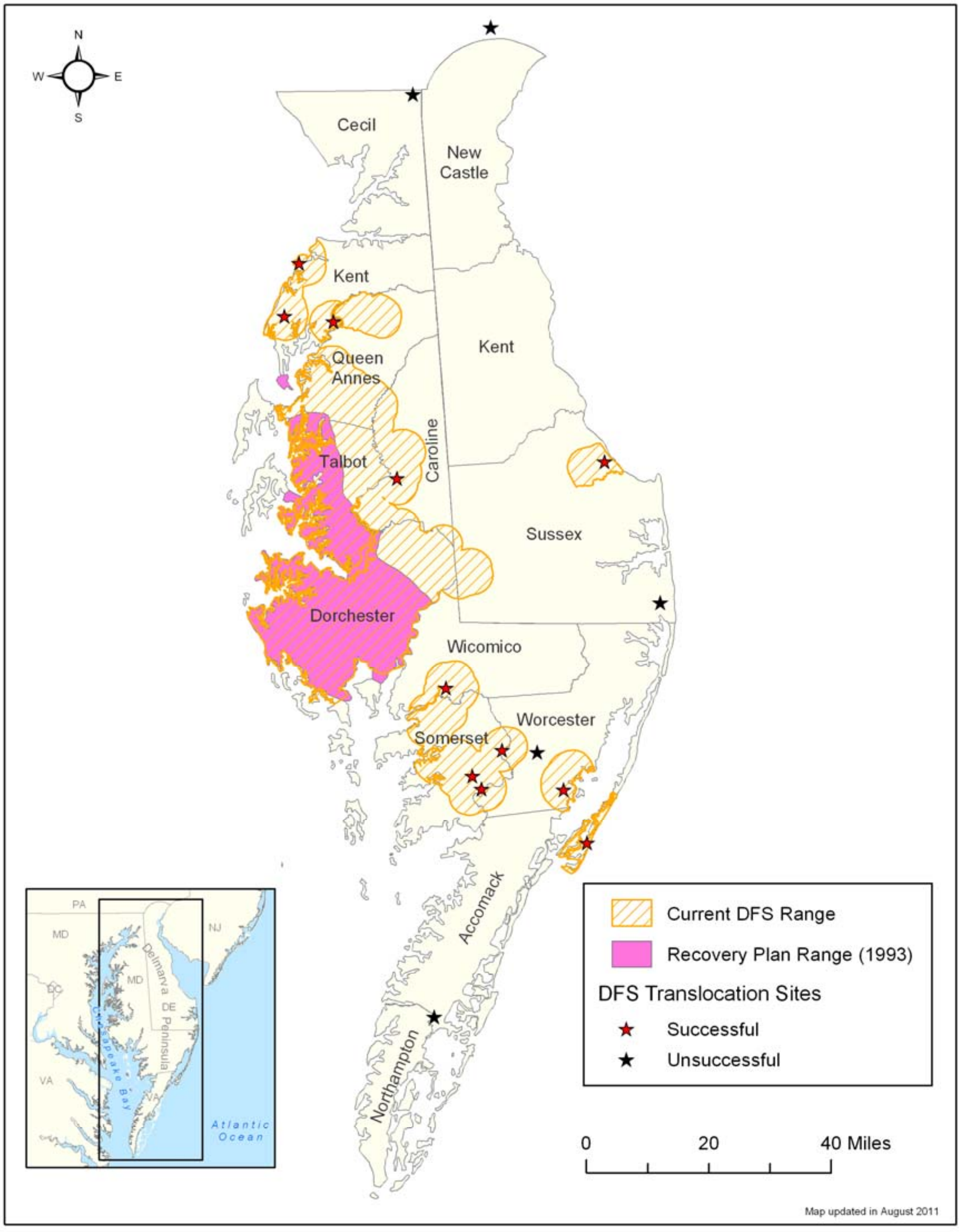

Figure 2. Translocations to expand the range of the Delmarva fox squirrel.

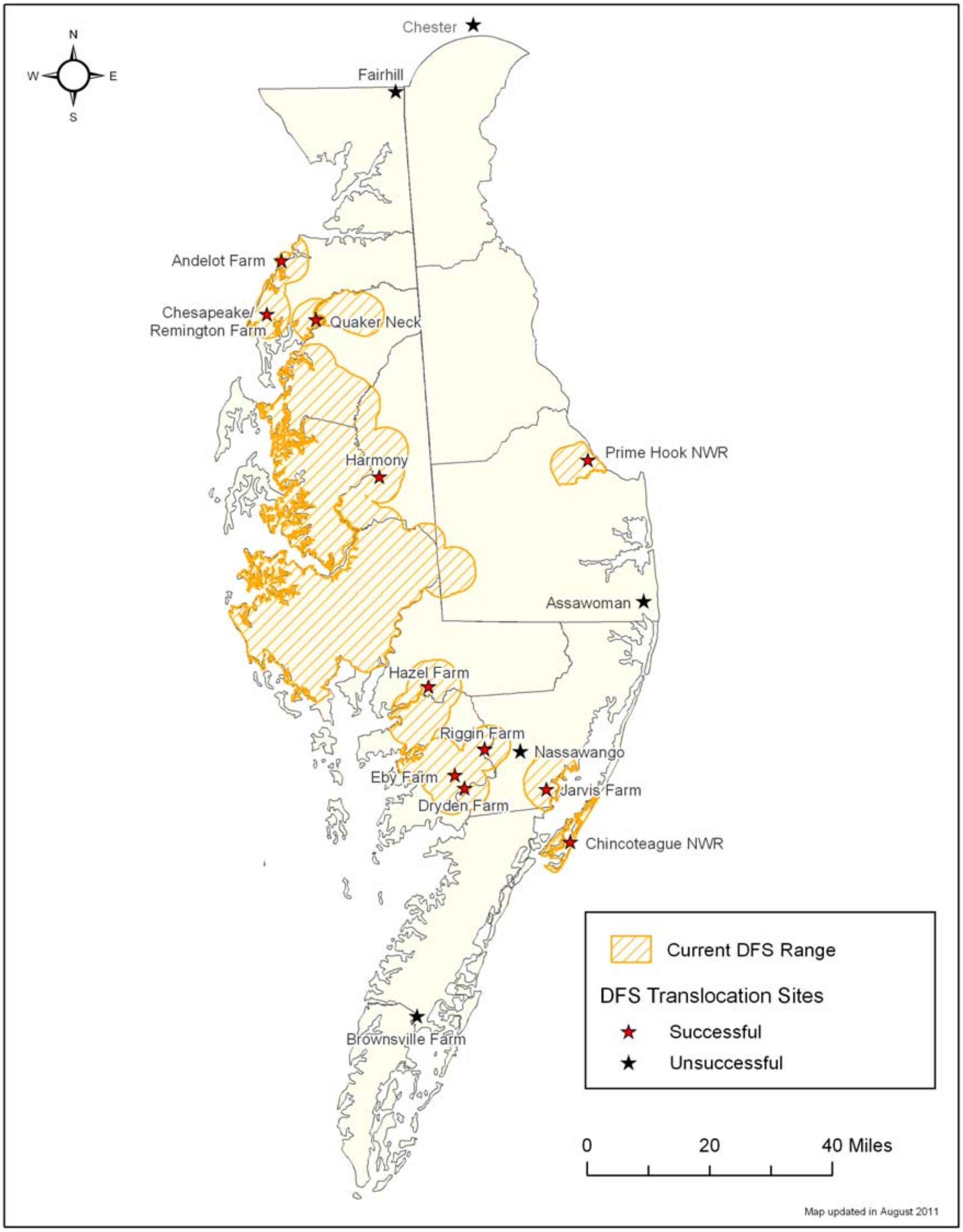

Figure 3. New Delmarva fox squirrel sightings connecting subpopulations identified in the past Status Review.

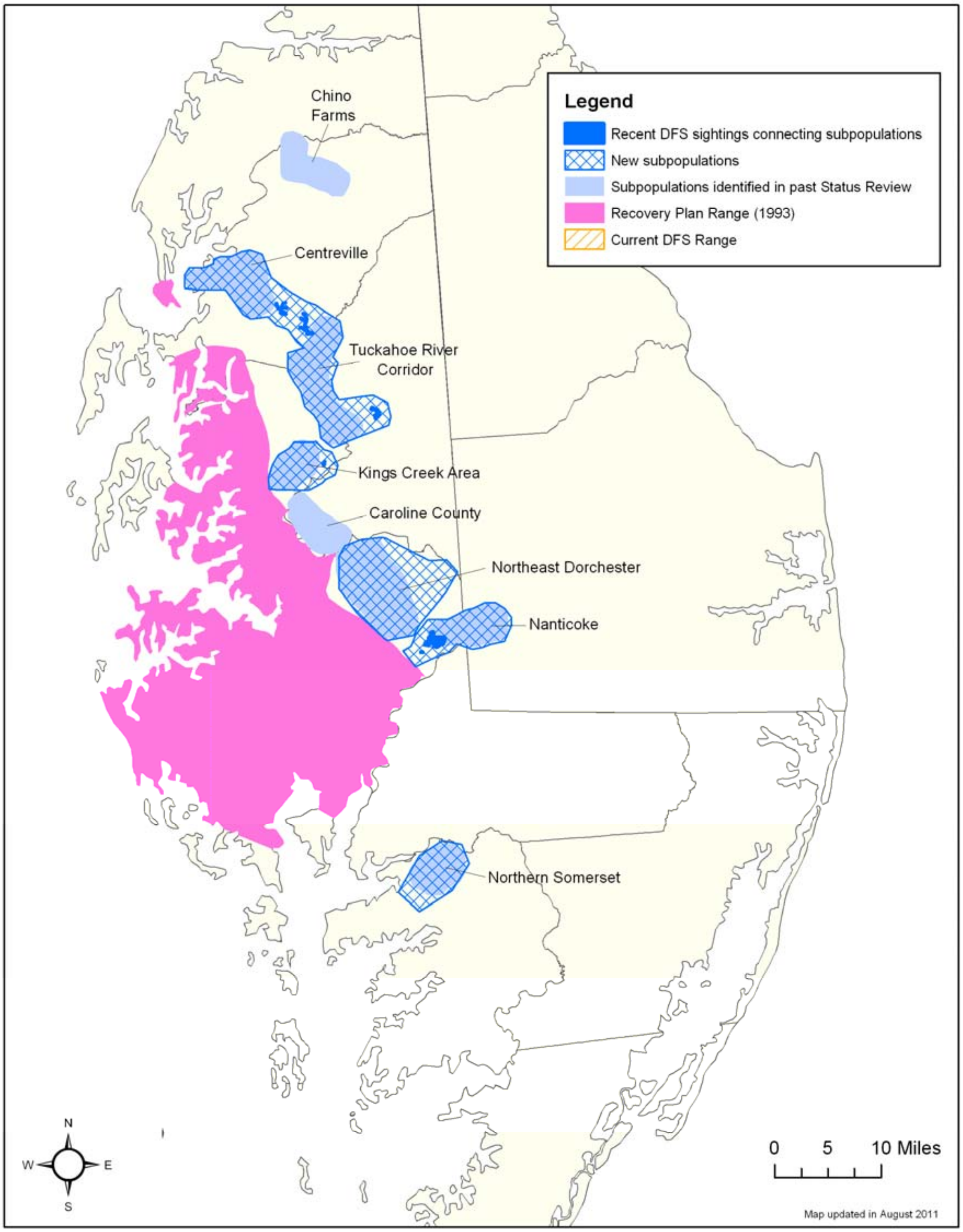

Figure 4. Changes in occupancy of forest tracts identified as occupied in 1990.

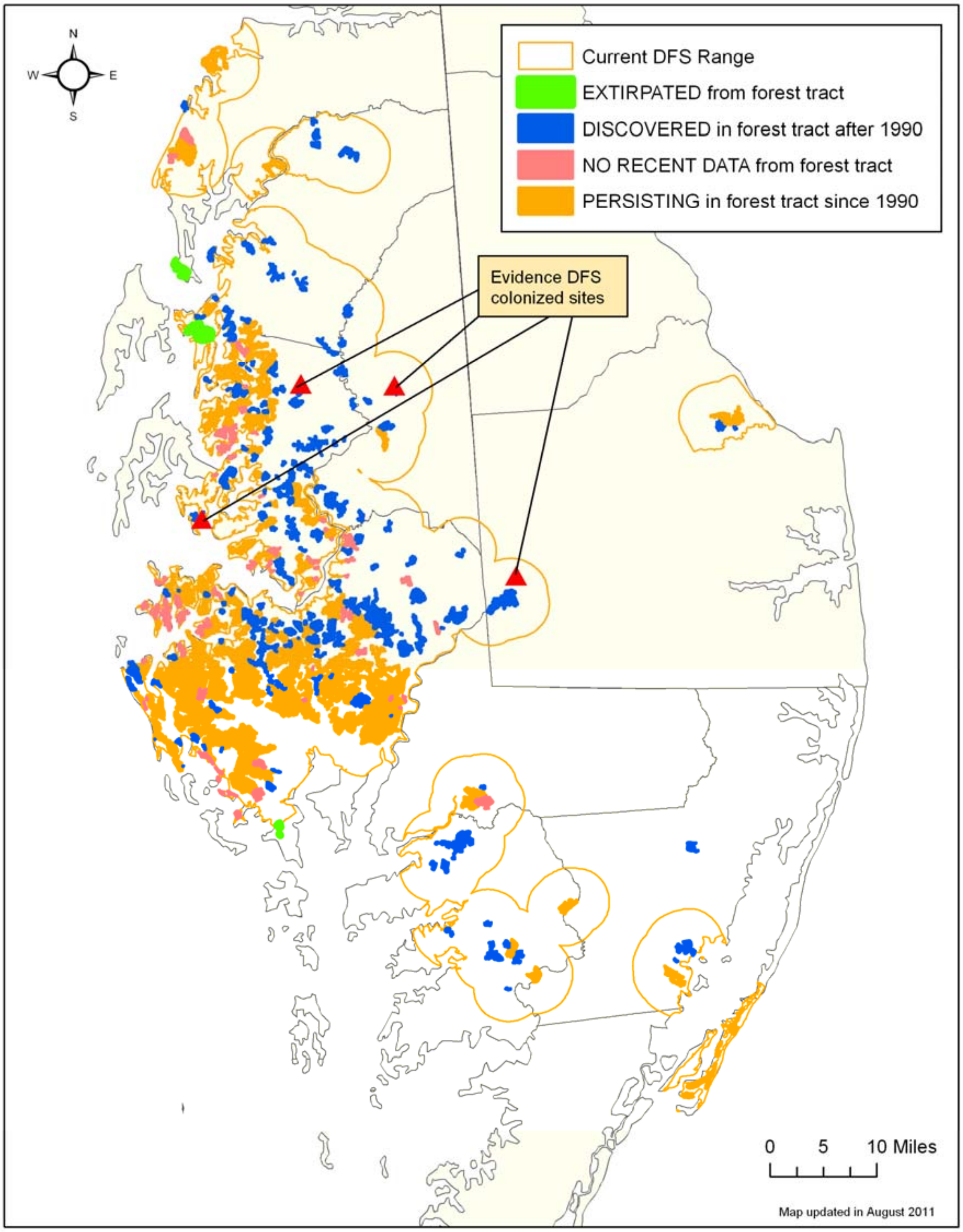

Figure 5. Extirpation risk of 2010 subpopulations based on size and isolation.

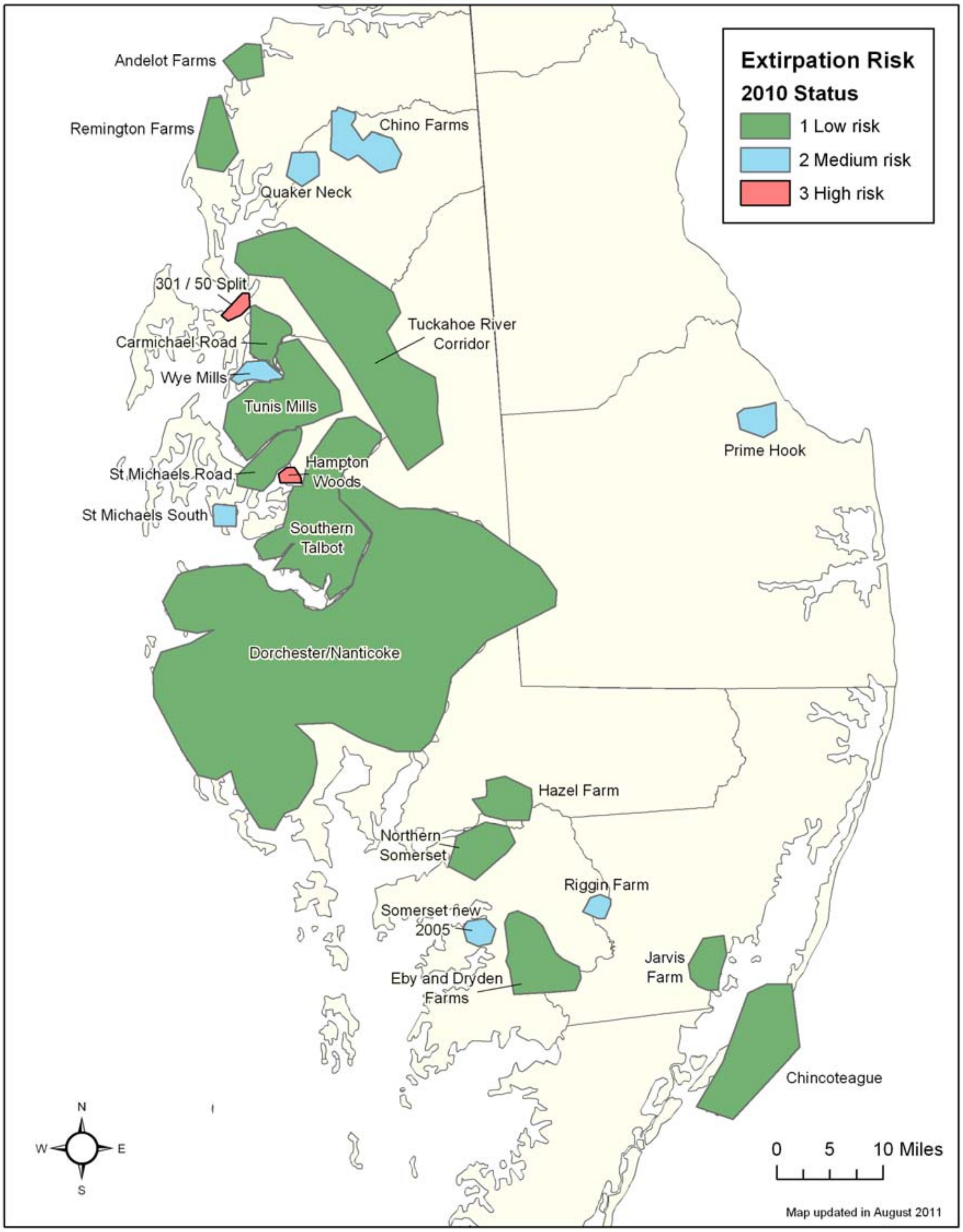

Figure 6. Land Use / Land Cover on the Delmarva peninsula.

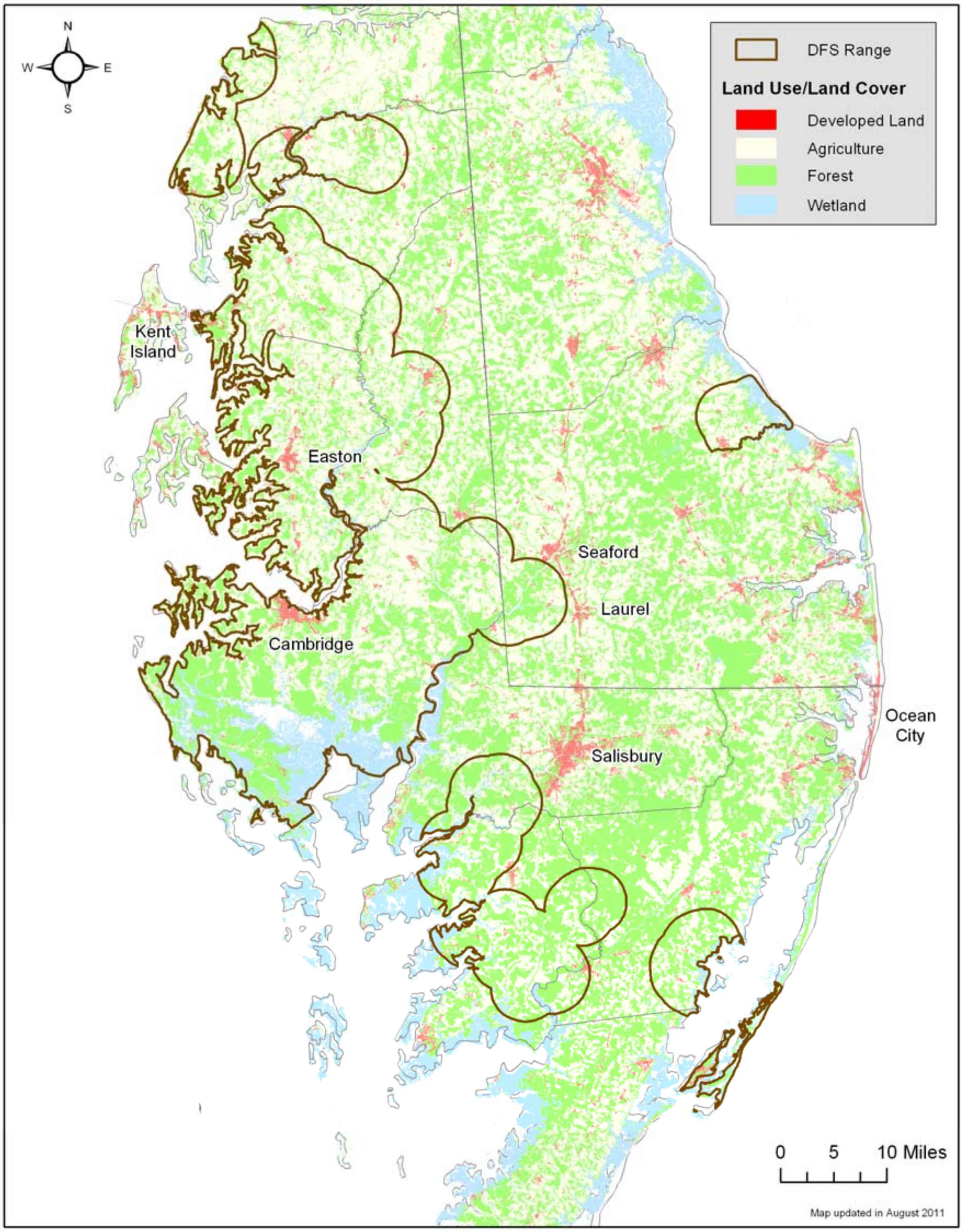

Figure 7. Lands protected from development.

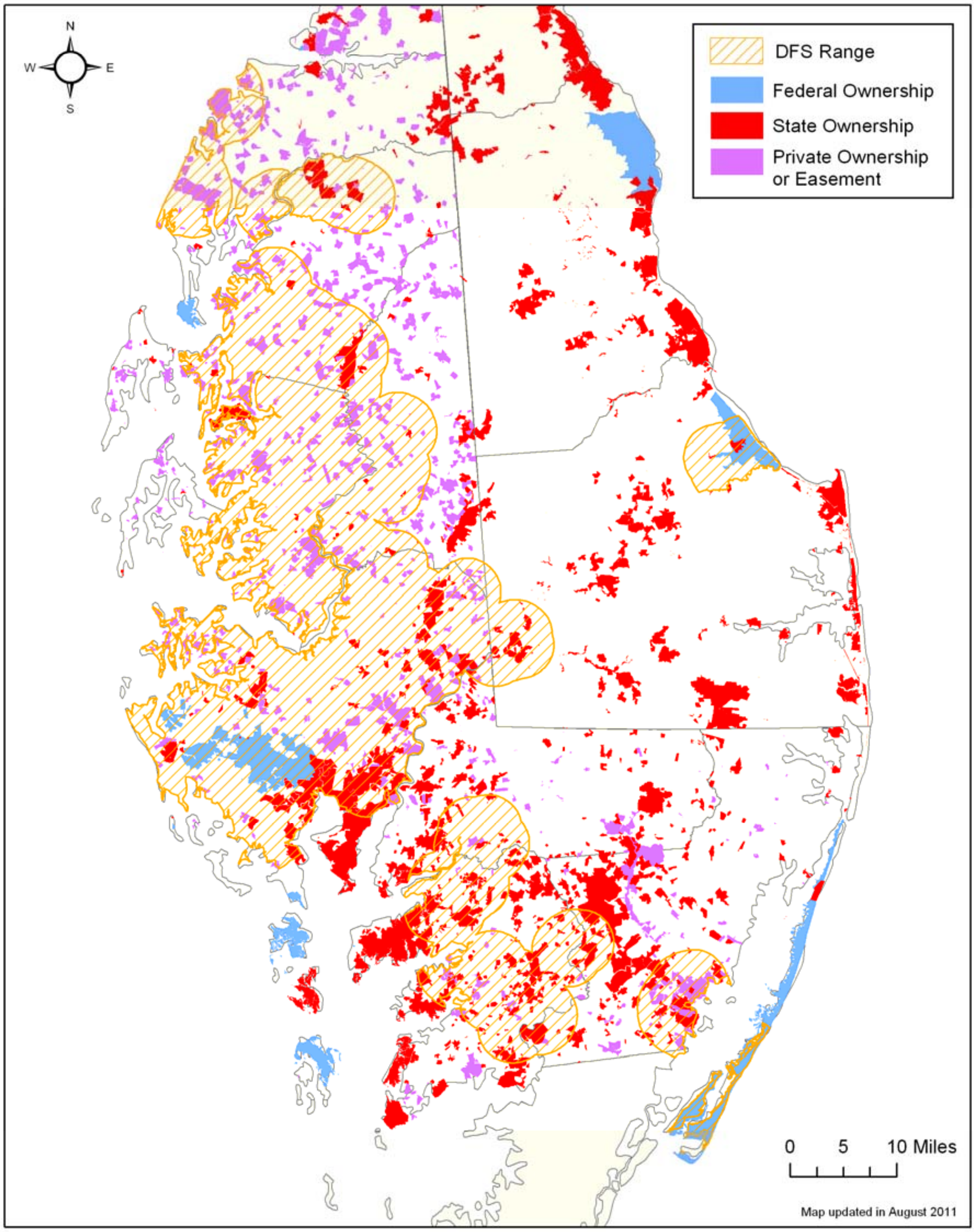

Figure 8. The distribution of mature forest suitable for Delmarva fox squirrels as defined by a LiDAR habitat model.

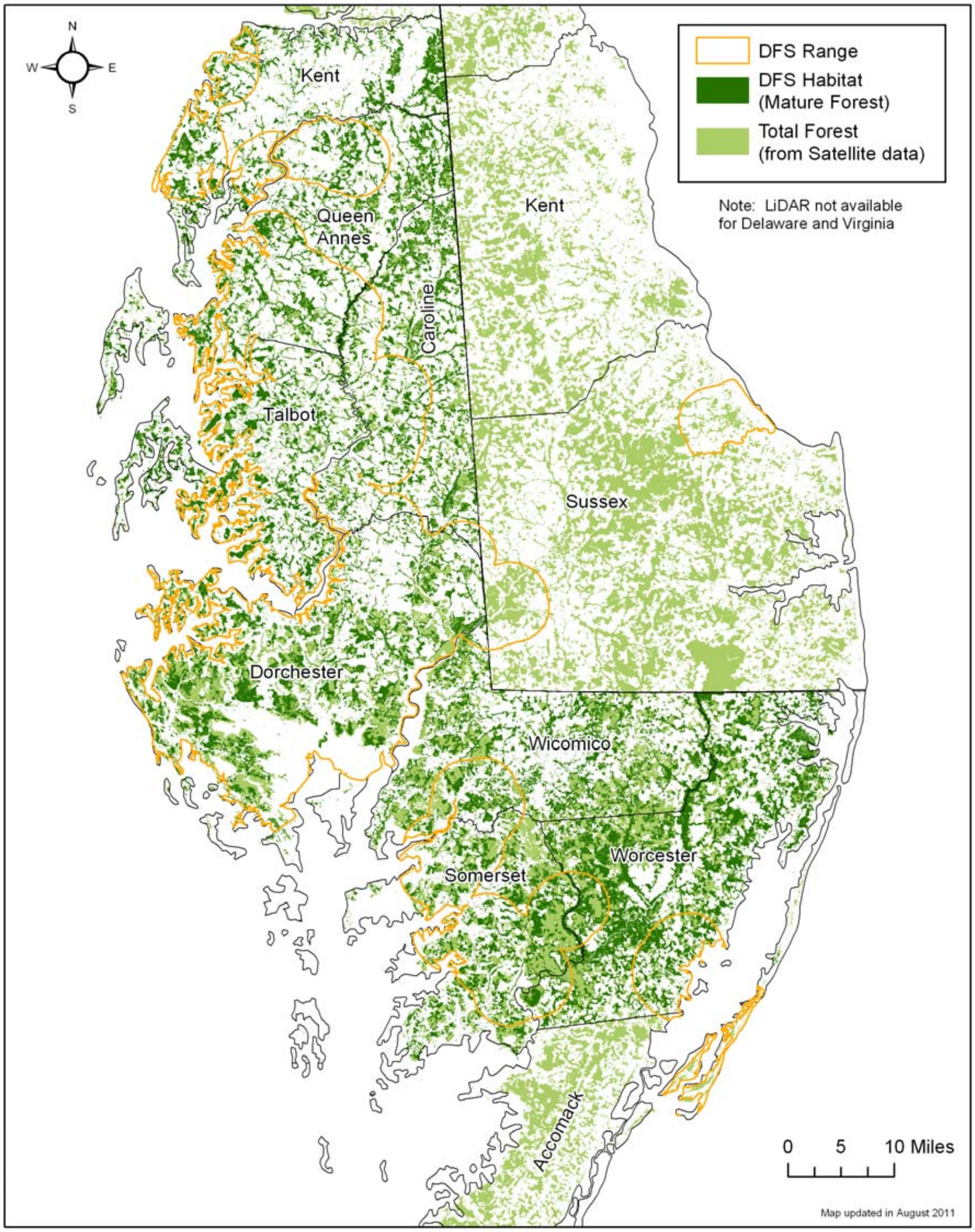

Figure 9. Connectivity of 175-hectare forest patches using jwalk model.

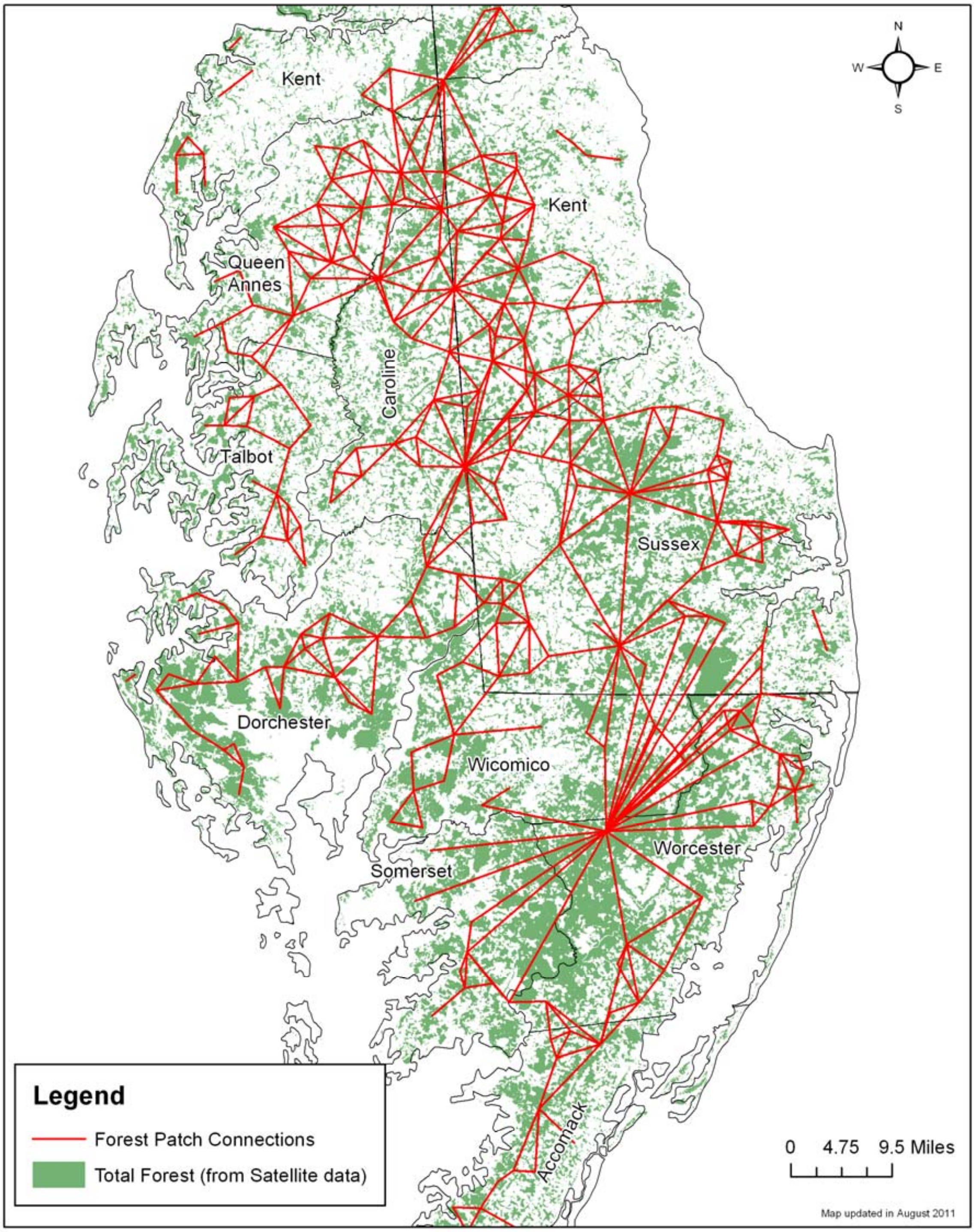

Figure 10. Connectivity of DFS subpopulations to 175-hectare forest patches using jwalk model.

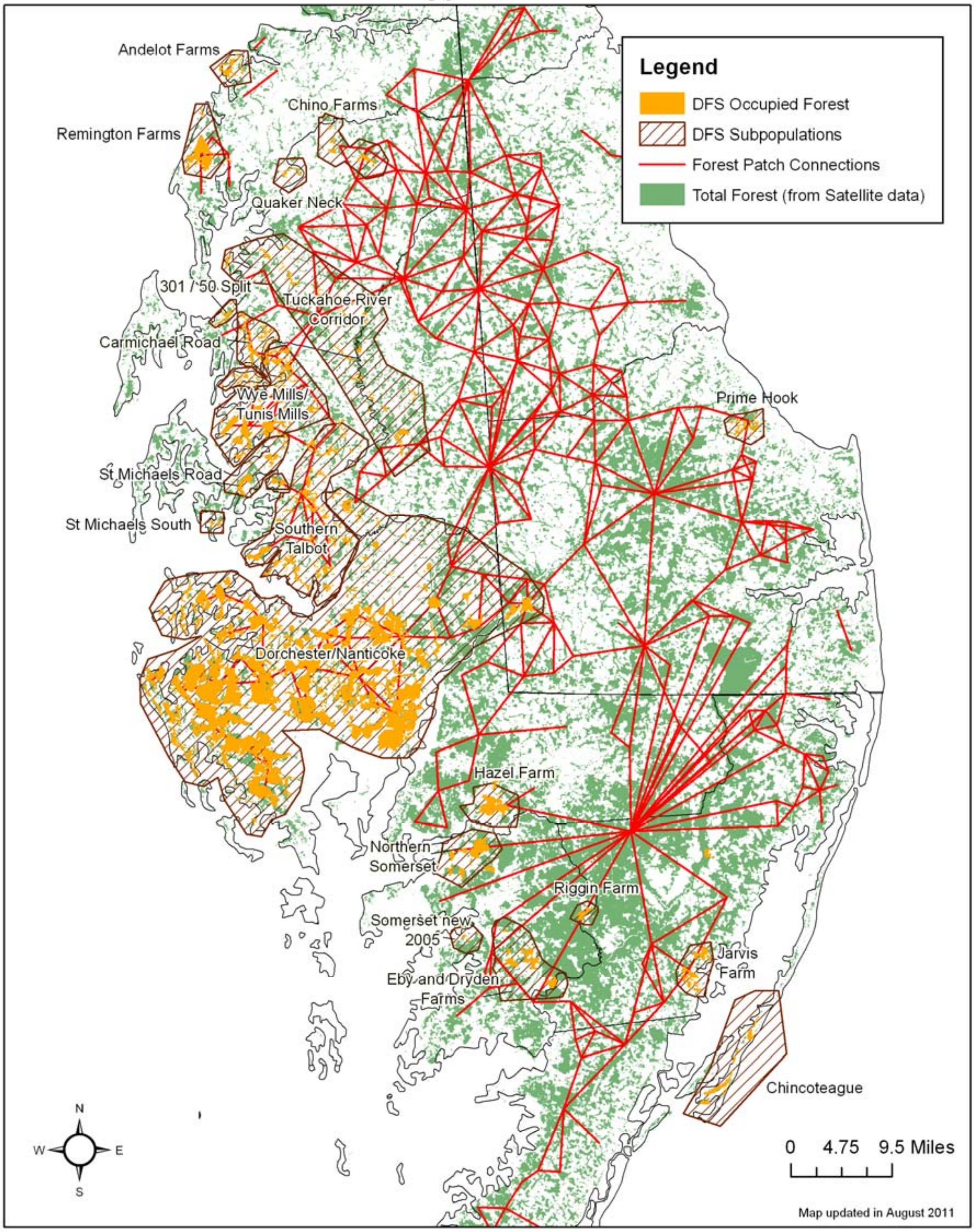

Figure 11. DFS distribution in relation to future development in smart growth areas in Maryland or municipalities in Delaware

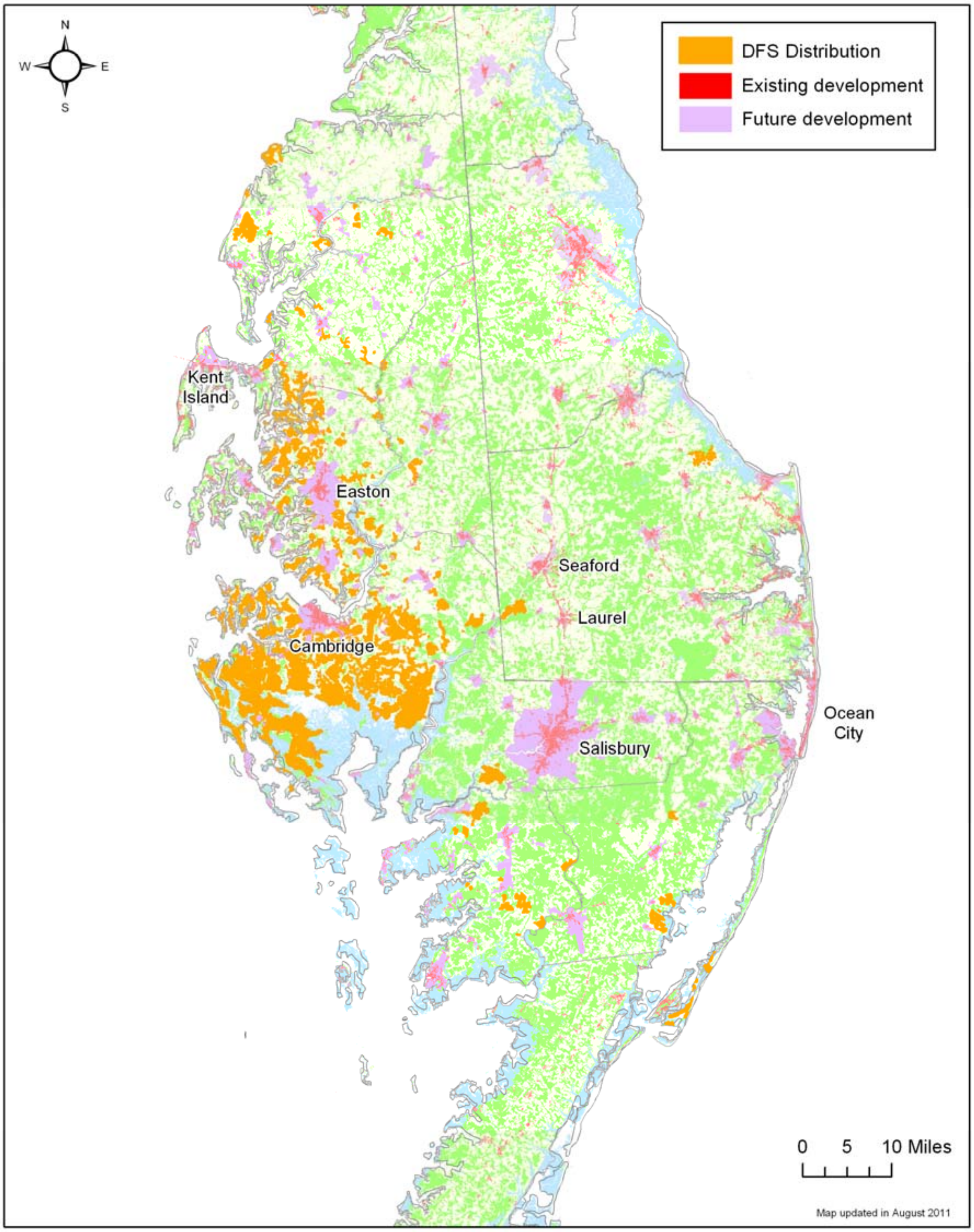

Figure 12. Land remaining after a 2-foot inundation (in Maryland) and DFS occupied forest lost through inundation and isolation. Arrows indicate areas where DFS are expected to move inland over time.

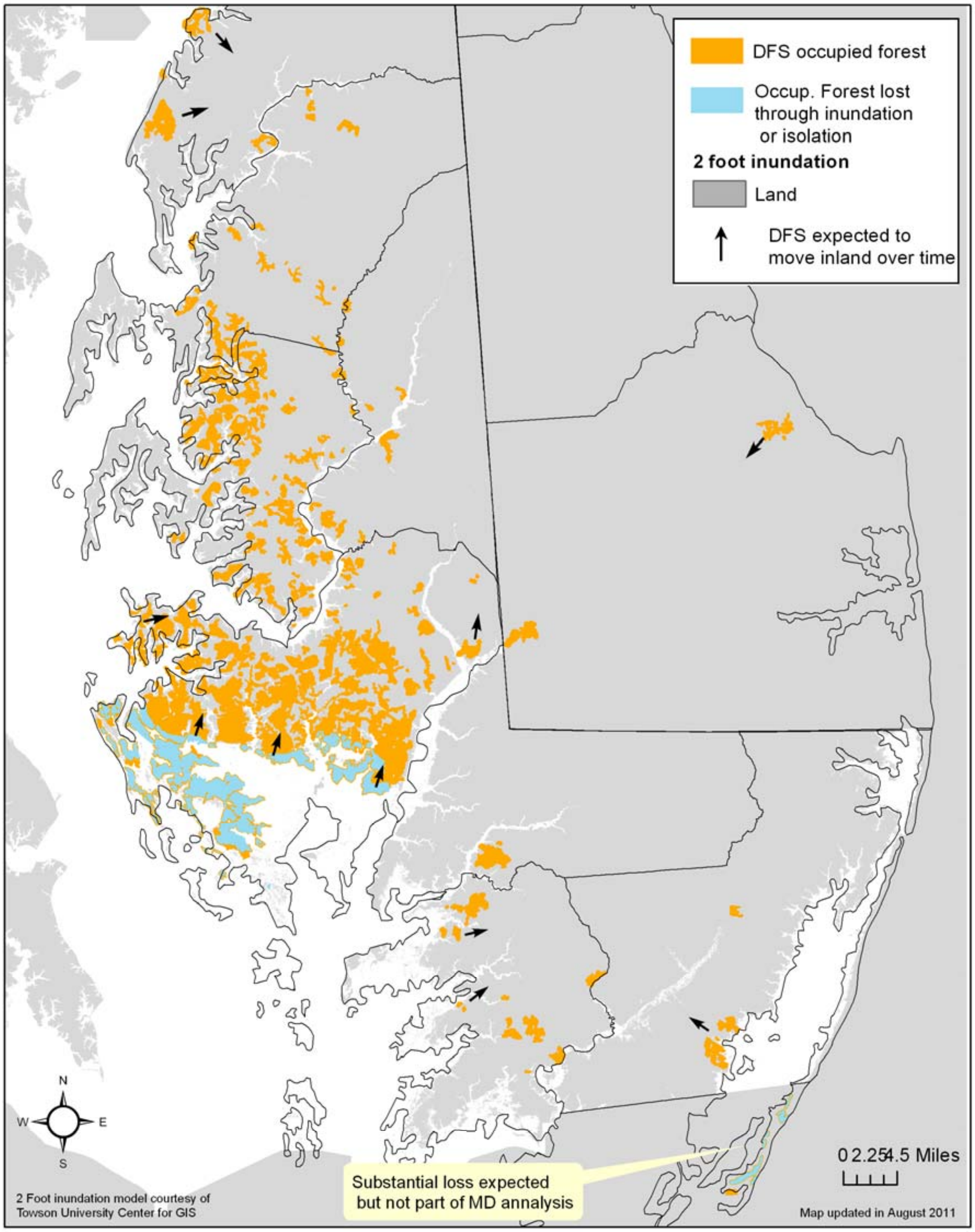

Figure 13. Location of DNR owned Chesapeake forest lands.