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Public Comments Processing
Attn: FWS-R5-ES-2015-0122
U.S. Fish and Wildlife Service
MS: BPHC
5275 Leesburg Pike
Falls Church, VA 22041-3803

To: Wende Mahaney and all whom this concerns
In re: Wood Turtle – docket #: FWS-R5-ES-2015-0122
http://www.regulations.gov/#!docketDetail;D=FWS-R5-ES-2015-0122

To all whom this concerns,

My comments are as follows:

(1) The species' biology, range, and population trends, including:

(a) Habitat requirements

After America's four Tortoise and two Box Turtle species, the Wood Turtle is the most terrestrial of our nation's 59 turtle species (see Ernst and Lovich 2009). Generally associated with wooded streams, Wood Turtles are also North America's most amphibious turtle species, requiring a mosaic of wetland and upland habitats in which to survive and carry out their complex biphasic (aquatic & terrestrial) life history. Their use of these varying habitat associations depends upon seasonal, circadian, geographic, and weather-related factors. The Turtles depend upon this diversity of habitats for foraging, nesting, basking, cover, hibernation, osmoregulation, and other needs. In various parts of their range the Turtles use such terrestrial habitats as deciduous, mixed, and coniferous forests and associated shrubland (such as alder thickets), meadows and glades, fields, and pastures.

The natural habitat patchiness in the Turtle's range is reflective of a mosaic of soil types, topographic conditions, microclimates, seral stages, and disturbance regimes (McNab and Avers 1994, Law and Dickman 1998, Lorimer and White 2003, Rentch 2006). In addition to moisture, edaphic, elevation, and topographic gradients (McEwan and Muller 2006; Lawrence *et al*. 1997; Braun 1950; Ashe 1922), disturbance events and associated canopy gaps (Runkle 1991b; Glasgow and Matlack 2007a&b) are major factors structuring understory and overstory vegetation in deciduous forests of the eastern United States.

A disturbance regime of small-scale, within-stand gap processes dominated the natural forests in the northeast region inhabited by the Wood Turtle (Runkle 1985 & 1990, Mladenoff *et al*. 1993, Seymour *et al*. 2002, Rentch 2006, North and Keeton 2008). For example, White *et al*. (2004) found that "in different forest types (including hardwood, mixed wood, cedar seepage, cedar swamp, mixed conifer, and spruce) . . . [i]nstead of stand-replacing events, small gaps (< 0.1 ha) have dominated the disturbance history of these plots [in northern Maine]." This natural disturbance regime of relatively small-scale canopy disruptions occurs through such mechanisms as windthrow, tree senescence, ice storms, drought, insects, Beavers, floods, and pathogens (Braun 1950, Rentch 2006).

Large "catastrophic" stand replacing events, such as hurricanes and conflagrations, are naturally a rare occurrence. Most of the Turtle's range is outside of the zones of frequent hurricanes and stand replacing fires have very long return intervals (Lorimer and White 2003) For example, a natural fire rotation in northern hardwoods was estimated to be 1070 years, the fire rotation periods in spruce-hardwoods were estimated to be 1253-1519 years, and the period for severe windthrow in the mixed spruce–hardwood forests and northern hardwood dominated forests on the better soils was 2585 years (*id*.).

The congruence and harmonization, and lack thereof, of human disturbance (*i.e*., cutting regimes) with the spatial and temporal parameters of natural disturbance (Flamm 1990, Seymour *et al*. 2002, Lorimer and White 2003, Franklin *et al*. 2002, Keeton 2004, North and Keeton 2008) are of concern throughout the Turtle's range. Researchers in northern Maine found that "[t]he most obvious silvicultural analogs to this disturbance history are individual tree selection and group selection systems." (White *et al*. 2004)

The scale and intensity of logging do not happen in a vacuum; even if in and of itself such activity is considered to be tolerable, the attendant indirect impacts and the cumulative impacts of the other factors at a locality must be considered. Wood Turtles can be tolerant of mild habitat alterations such as small-scale openings in the streamside canopy that may create foraging or nesting areas (Harding 1991). However, even the benefits of such relatively small-scale activity can be offset by effects of harvest machinery (*e.g.,* compaction of soil, destruction of nesting habitat, the crushing of Turtles), harmful edge effects (*e.g*., facilitation of depredation and invasive plants), and sedimentation ((Saumure *et al*. 2007). Certainly within the Turtle's "core habitat" zones it is sensible in general to minimize human disturbance and allow the dynamic of natural processes to be expressed.

It is sometimes stated or implied that the Wood Turtle does not prefer "contiguous forested habitat" or that it is not a "wilderness" species. There may be a problem here with nomenclature, concept, or perception.

A forest can be contiguous yet have numerous canopy openings due to a variety of natural disturbances (McCarthy 2001). In fact, this is the natural state of wild old growth forests in this part of the country (Davis 1996). And it is such forests that the Turtle has lived in and has adapted to over the course of its evolutionary history. Mature forests are of the age that a mosaic of habitats is developing and has developed over time due to the operant disturbance regime (Franklin *et al*. 2002). And still more such niche complexity (including canopy openings and loadings of large woody debris (LWD)) can be expected to develop as mature forests become old growth (Dahir and Lorimer 1996). Such naturally developing forests (of sufficient age) are composed of various seral stages and typically include patches dominated by young trees, older early successional forest, mid-successional forest, young late successional forest, and old late successional forest (Frelich and Reich 2003, Franklin *et al*. 2002). Due to the continuous nature of disturbance and developmental processes, many natural eastern forests have been called all-aged or uneven aged (North and Keeton 2008, Burrascano *et al*. 2013).

Thus, it is not apparent that natural "contiguous forested habitat" is in any way problematic for this species or that it is not preferable. In fact, evidence and reason point to just the opposite. In the absence of human logging/cutting/clearing disruptions, maturing and old-growth forest tracts undergoing natural disturbance support numerous tracts of different forest types and ages as well as microhabitat patches that are used by wildlife on a fine scale (Fahrig and Merriam 1994, Law and Dickman 1998). This is certainly the case for Wood Turtles at my study sites in the Ridge and Valley physiographic province in VA (Shenandoah and Frederick Counties) and WV (Hardy County) (Krichbaum unpub. data; see Table 1; see Attachment for site description).

Wood Turtles can typically be found near, in, or at the edges of small canopy gaps or semi-gaps and/or in low-lying vegetation in mature deciduous forest (Akre and Ernst 2006, Remsburg *et al*. 2006, Krichbaum 2009, Krichbaum unpub. data). Such places provide cover from predators, while the dappled sunlight and/or small size of these sites allow the Turtles to vary thermal and moisture factors with ease and efficiency, as only small movements are necessary to be in either sunlight or shade.

Wood Turtles do not need large clearings for thermoregulation. They are not large animals, nor do they travel in herds. A sunlit space a foot-square is easily of sufficient size for basking. In fact, using a large open site could increase their exposure to predators or human collectors. Wood Turtles cannot run away, nor can they slip out of sight into water as do aquatic turtle species that prominently bask. Exposure on land can easily lead to injury or mortality; camouflage, cover, and inconspicuity are key to survival for this species.

Canopy gaps are major factors structuring understory and overstory vegetation in deciduous forests of the eastern United States (Glasgow and Matlack 2007b), such as sustaining herbal growth, richness, and persistence (Anderson and Leopold 2002). Natural canopy gaps are also often associated with large downed trees. Wood Turtles prefer sites with greater amounts of LWD than is randomly available (Krichbaum, unpub. data; Table 2).

In Virginia and West Virginia Wood Turtles are found in forests with 39 woody species in the overstory and midstory (trees $\geq$ 25cm dbhand 10-25cm dbh respectively). The "importance values" (based on basal areas and counts of each species at a site) of the dominant species are at Table 3. As the values indicate, a greater proportion of sites in WV are mixed (deciduous – pine) or pine forests than in VA (also see Fig. 2).

Ecological communities/vegetation types (as per Fleming and Couling 2001) where Wood Turtles have been observed on the George Washington National Forest in VA and WV include: Central Appalachian ("C.A.") acidic oak – hickory forest, Chestnut Oak – Northern Red Oak forest, Mixed oak – heath forest, Northern Appalachian xeric oak/heath forest – Chestnut Oak/low elevation subtype, C.A. White Pine – xeric oak forest, C.A. xeric shale woodland (both Virginia Pine and Chestnut Oak types), C.A. rich cove forest, C.A. White Pine - Eastern Hemlock forest, C.A. small-stream montane forest, C.A. basic seepage swamp, and C.A. acidic seepage swamp (Krichbaum unpub. data).

Most of these forest types/communities that I have observed Wood Turtles using are drier upland types that are not confined to riparian areas (see Fig. 8 for just one example).

Turtles at both the VA and WV sites present a strong degree of philopatry. Individuals have been found in multiple years at the same general locations. In thirty+ field searches in the period 2006-2014 at the WV site fifty-nine adults were captured 125 times, with thirty-two being recaptured at least once; of the sixty-six total recaptures, all were adults. Of the 59 adults, 54.2% were female and 45.8% male. Nineteen of the thirty-two Turtles recaptured were female (59.4%) and 13 were male (40.6%). Three males were observed six different years and one male was observed five years. One female turtle was found in in five different years, with four others being found in three years or more (Krichbaum unpub. data). Some of the Turtles at the VA site have been found there for almost two decades (Akre unpub. data).

The important herbaceous species at Wood Turtle locations in VA and WV are tabulated in Table 4a-f. Very few of these species are wetland taxa (as per Lichvar *et al.* 2014). My analyses indicate that Turtles prefer sites with greater herbaceous richness and cover than what is randomly available (Table 2, Fig. 3) (also see Compton *et al.* 2002, Akre and Ernst 2006, Tingley *et al.* 2010).

Over a four-year field study in VA and WV, I obtained 679 GPS locations of *ca.* 100 Wood Turtles. The greatest distances from the mainstreams were 289-667 meters (VFT:484m, VMT:289m, WFT:466m, WMT:667m, with 95% of the locations within approximately 290-295m of the mainstreams in each state (see Fig. 1a-b). This is congruent with numerous other studies.

In Virginia, movement patterns at all three of Akre and Ernst's (2006) study areas were found to be similar and consistent with other studies. At the agricultural site, 90% of all locations were within 250 m of the stream, while at the forested site, 95% of locations were within 300 m of the stream, and at the moderately altered forest site, 95% of locations were within 200 m of the stream. Turtles were found to range over 500 meters from the streams in Ontario (Foscarini and Brooks 1997; Quinn and Tate 1991). In Nova Scotia, 95% of female locations were within 235m of the study stream (Tingley *et al*. 2009). In the Ridge and Valley ecoregion of Pennsylvania the maximum distance was found to be 600 meters (Kaufmann 1992). In a Quebec study all sightings were made within 300 meters of streams used by the Turtles (Arvisais *et al*. 2002). In West Virginia male Wood Turtles have been observed up to 400-600 meters from streams (Krichbaum 2009). At another West Virginia study site the greatest known distance traveled from a river was approximately 200 meters (Niederberger and Seidel 1999). In Michigan's Huron National Forest, "92.5% were within 200 m of the river. Ten of 29 telemetered turtles moved > 200 m from the river . . . Only 2 turtles, composing less than 4% of turtle locations (n=36), traveled more than 500 m from the river" (Remsberg *et al*. 2006). In Maine, 95% of Turtle activity areas were within 304 m of rivers and streams (Compton *et al*. 2002). In New Hampshire 95% of captures and recaptures were recorded within 175 meters of water (Tuttle and Carroll 2003). While a study conducted in both Massachusetts and New Hampshire found 228 meters to be the "distance representing the 75th percentile of all radio-equipped animal's median distance traveled from water between July and August of all years." (Jones 2009) In this same study 470 meters represented the 95th percentile median distance from water, with maximum distances being 634-932 meters (*id*.).

From the above information and empirical data, it is clear that Wood Turtles are not confined to narrowly defined "riparian areas". They typically use upland forests far from streams at sites with woody and herbaceous plants that are not strictly "riparian" or "wetland" species.

Wood Turtles do not seem to use habitats randomly, suggesting they actively select their habitat (Akre and Ernst 2006, Arvisais *et al*. 2004, Compton *et al*. 2002, Kaufmann 1992, Strang 1983, Tingley *et al*. 2010, and Krichbaum unpub. data). For example, see non-metric multi-dimensional scaling (NMDS) graphs comparing habitat variables at WT plots with those at random plots from my research sites in VA and WV (Fig. 2a-d and Table 8; also see Table 7 for matched pairs logistic regression variables).

(b) Genetics and taxonomy

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(c) Historical and current range, including distribution patterns

In the United States the Wood Turtle occurs in the following large-scale forest regions (and section) as defined by Braun (1950) and Dyer (2006):

Mesophytic Region (VA, MD, DE)

- Appalachian Oak Section of the Mesophytic Region (VA, WV, MD, PA, NJ, NY, CN, RI, MA,NH, ME)
- Beech – Maple – Basswood Region (PA, NY, WS, MN, IA)
- Northern Hardwoods – Hemlock Region (PA, NY, CN, MA, VT, NH, ME)
- Northern Hardwoods – Red Pine Region (MI, WS, MN).

In the United States the Wood Turtle's range (see Ernst and Lovich 2009) includes the following large-scale ecoregion "provinces" and "sections" (*sensu* Avers *et al*. 1994, Bailey *et al*. 1994, McNab and Avers 1994, and McNab *et al*. 2007):

- Outer Coastal Plain Mixed Forest Province 232 (MD, VA)
  - Middle Atlantic Coastal Plain 232A
- Southeastern Mixed Forest Province 231 (VA, MD)
  - Southern Appalachian Piedmont 231A
- Central Appalachian Broadleaf Forest – Coniferous Forest – Meadow Province M221 (VA, MD, WV, PA)
  - Northern Ridge and Valley M221A (VA, MD, WV, PA)
  - Allegheny Mountains M221B (MD, WV, PA)
  - Blue Ridge Mountains M221D (VA, MD, PA)
- Eastern Broadleaf Forest (Continental) Province 222 (PA, NY, WS, MN, Iowa)
  - Erie and Ontario Lake Plain 222I (PA, NY)
  - Southwestern Great Lakes Morainal 222K (WS)
  - North-Central U.S. Driftless and Escarpment 222L (WS)
  - Minnesota and Northeastern Iowa Morainal 222M (WS, MN, IA)
- Eastern Broadleaf Forest (Oceanic) Province 221 (WV, PA, DE, NY, NJ, CN, MA, RI, VT, ME)
  - Lower New England 221A (NJ, NY, CN, RI, MA, NH, ME)
  - Hudson Valley 221B (NY, MA, VT)
  - Upper Atlantic Coastal Plain (DE, NJ)
  - Northern Appalachian Piedmont 221D (MD, PA, NJ, NY)
  - Southern Unglaciated Allegheny Plateau 221E (PA)
  - Western Glaciated Allegheny Plateau 221F (PA)
- Laurentian Mixed Forest Province 212 (PA, NY, VT, ME, MI, WS, MN)
  - Aroostook Hills and Lowlands 212A (ME)
  - Maine and New Brunswick Foothills and Eastern Lowlands 212B (ME)
  - Fundy Coastal and Interior 212C (ME)
  - Central Maine Coastal and Interior 212D (ME)
  - St. Lawrence and Champlain Valley 212E (NY, VT)
  - Northern Glaciated Allegheny Plateau 212F (PA, NY)
  - Northern Unglaciated Allegheny Plateau 212G (PA)
  - Northern Great Lakes 212H (MI, WS)
  - Southern Superior Uplands 212J (MI, WS)
  - Western Superior 212K (WS, MN)

Northern Superior Uplands 212L (MN)
Northern Minnesota Drift and Lake Plains 212N (MN)
Adirondack – New England Mixed Forest – Coniferous Forest – Alpine Meadow Province M212 (NY, VT, NH, MA)
White Mountains M212A (VT, NH, ME)
New England Piedmont M212B (MA, VT, NH)
Green, Taconic, Berkshire Mountains M212C (CN, MA, VT)
Adirondack Highlands M212D (NY)
Catskill Mountains M212E (NY)

See Jones and Willey (2015) for watersheds in the NE USA inhabited by the Wood Turtle.

(d) Historical and current population levels, and current and projected trends

The Wood Turtle is considered to be in some sense 'imperiled' in virtually every state in which it occurs (*e.g.*, the Wood Turtle is state Endangered in Iowa, state Threatened in Minnesota, Virginia, and Wisconsin, and a species of Special Concern in Michigan). As of November of 2010 the Turtle was considered "apparently secure" in only two (Maryland and Maine) of the 22 states and provinces where they are known to occur (NatureServe 2015). See Jones and Willey (2015) for a recent review of state statuses.

In Canada, the Turtle's status was re-examined and it was designated as "Threatened" throughout the country in November 2007 (COSEWIC 2007). "A crude estimate of total population size of the Wood Turtle in Canada, based on quantitative estimates from researchers across its Canadian range, is ~6,000-12,000 adults. Wood Turtle populations that are in areas to which people have limited access may be stable, but where there is road access many populations are declining, and the overall trend in Wood Turtle abundance over the past three generations (~100+ years) is also one of decline." (*id.*)

The species is already absent from a significant part of its historic range. There is evidence of population extirpations or declines and a general range contraction (Ernst and McBreen 1991, Farrell and Graham 1991, Harding 1991, Klemens 1993, Garber and Burger 1995, Lovich 1995, Litzgus and Brooks 1996, Levell 1997, Burke *et al*. 2000, Harding 2002, Daigle and Jutras 2005, Tessier *et al*. 2005, Akre and Ernst 2006, COSEWIC 2007, Saumure *et al*. 2007, Tingley *et al*., 2009, Jones 2009, Willoughby *et al*. 2013, Jones and Willey 2015).

At present, there is much apparently "suitable" Wood Turtle habitat that is not inhabited (Akre and Ernst 2006, Krichbaum, S. pers. obs., Oldfield 1996, COSEWIC 2007, Jones and Willey 2015). For example, there are occurrence records for the Turtle in Virginia from the relatively recent past (*i.e.*, 50 years ago in southern Rockingham County), but contemporary surveys have not found any Turtles there now. Only a restricted number of creeks and rivers in the Turtle's range retain clear water, undisturbed nesting sites, deep pools for overwintering, and undisturbed upland zones. This habitat loss and degradation is due to agricultural activities, development, channelization, dams, contamination, roads, and forestry activities. In addition, any increase in access (by humans and/or predators) to Turtle populations constitutes a degradation of habitat even before direct physical habitat modification occurs.

Over the course of five years (2005-2010) I searched many stream sites on the GWNF in Virginia and West Virginia that are within the Turtle's range and ostensibly have suitable WT habitat (*e.g.*, low gradient streams with rocky substrates, low elevation, forests). Out of around 70 streams, many of which were searched multiple times, at only 12 did I find Wood Turtles (of course, this is not to say that the species definitely does not occur at the other 58 sites) (Krichbaum unpub. data, Table 9).

The Wood Turtle, as do most turtle species, possesses life history traits that make populations especially vulnerable and sensitive to increased human-caused loss and mortality: slow growth, late maturity, high natural mortality of eggs and hatchlings (such as from predators), high survival of adults, long lives, and low reproductive potential (Congdon and Gibbons 1990, Lovich *et al*. 1990, Gibbs and Amato 2000, Heppell *et al*. 2000). After reaching maturity, turtles must then survive and reproduce for decades more just to replace themselves (the "feasible demography" of Seigel 2005; Congdon *et al*. 1993 & 1994). High adult survivorship and extreme iteroparity are generally necessary to maintain turtle population viability (Doroff and Keith 1990, Heppell 1998, Heppell *et al*. 2000, Mitro 2003, Reed and Gibbons 2003). Due to the energetic and demographic implications of these traits, turtle populations may not be able to sustain even modest additive adult take/mortality (Congdon *et al*. 1993 & 1994, Enneson and Litzgus 2008). There is no apparent "density dependent" response operant (Congdon *et al*. 1993); *i.e.*, at low population levels there is no compensatory increase in birth rate or hatchling survival. In fact, just the opposite can reasonably be expected to occur, due to such factors as difficulty in finding mates (Belzer and Seibert 2009), *i.e.*, an Allee effect producing further reductions in population size. It is essential that conservation practitioners not address multiple/synergistic stressors to population viability individually in isolation (Crawford *et al*. 2014).

Population persistence involves a balance between exogenous ecological factors (that influence carrying capacity – "K") and endogenous evolutionary & demographic factors (vital rates that contribute to the population growth rate, "r" or "λ") (Kinniston & Hairston 2007). Demography can affect various evolutionary processes (Harts *et al*. 2014). The self-sustainability of populations in the long-term is a function of population size (Willi & Hoffmann 2009, Reed & McCoy 2014). Gene flow via dispersal is a key evolutionary process (Hoffman & Sgro 2011), so dispersal/ connectivity may be essential for maintaining MVPs and/or populations approaching K (Kinniston & Hairston 2007). Small populations are subject to greater stochastic impacts (genetic, demographic, environmental) that can erode viability (Lande 1993). Generally, a large N_e is needed to maintain genetic variation (Frankham 2003, Reed 2005); for example, Fridgen *et al*. (2013) reported lowered genetic diversity in reduced populations of Wood Turtles (*Glyptemys insculpta*) in southern Ontario. Fagan and Holmes (2006) analyzed declining populations of ten different vertebrate species, including two populations of Wood Turtles. They found that the time to extinction for the Turtle populations was less than 20 years. The populations began their final decline when composed of 31 and 58 individuals.

See this comment at "Population biology" for discussion pertaining to a Hardy Co., West Virginia population of Wood Turtles on the GWNF.

All of the above concerns and impacts underscore the importance of maintaining the ecological integrity and connectivity of (relatively) undeveloped sites and their intact populations.

(e) Past and ongoing conservation measures for the species, its habitat, or both

In Virginia a USFS road was closed to public vehicular use on the GWNF during the nesting Wood Turtle nesting season (*ca*. mid-May to July 4). Turtles use the cut banks for nesting at various sites along the length of this road. Closing it to vehicles can certainly help the Turtles. However, the north half of the road is opened back up to public motor vehicles during the rest of the summer and fall while the Turtles are terrestrially roaming and during the period nestlings are hatching and dispersing.

(2) The factors that are the basis for making a listing

(a) The present or threatened destruction, modification, or curtailment of its habitat or range (Factor A)

Even-age logging degrades Wood Turtle habitat in various ways.

Intensive cutting operations generally reduce litter and woody debris as well as alter soil structure, leaf litter, and humus. The availability and distribution of ground cover can change, as can thermal maxima and minima (Todd and Andrews 2008, Chen *et al*. 1999). Loadings of large woody debris on sites can be reduced for many decades after logging (Webster and Jenkins 2005). Amounts of large woody debris deposition are directly correlated with forest age (see Keeton *et al*. 2007, Spetich *et al*. 1999, Hedman *et al*. 1996). LWD amounts are naturally much higher in wild old growth forests than in the many relatively depauperate areas that characterize our landscape (Hedman *et al*. 1996, McMinn and Crossley 1996, Spetich *et al*. 1999, Webster and Jenkins 2005, Webster *et al*. 2008).

Fungi, herbaceous flora, and invertebrates, such as snails, slugs, millipedes, worms, and arthropods, that live in the forest floor litter or topsoil or are associated with LWD are a significant component of forest diversity. These organisms are also important food for Wood Turtles (Ernst and Lovich 2009, Jones 2009, Krichbaum pers. obs.). Logging's negative impact upon these organisms has thus far received little consideration from land managers. The concern is about significant impacts of logging upon the viability, abundance, diversity, and distribution of snails, slugs, millipedes, arthropods, earthworms, salamanders, fungi, and herbaceous plants, and in turn upon Wood Turtles. Food quality and quantity are important concerns (see, *e.g.*, Remsberg *et al* 2006).

Logging can influence the abundance and species composition of arthropods (Shure and Phillips 1991; Greenberg and Forrest 2003). Which arthropod taxa the Turtles feed upon or prefer is not precisely known. Macroarthropods may respond positively to the cooler, moister microclimates and greater cover and depth of leaf litter in unlogged sites; intensive cutting could result in declines of ground-occurring macroarthropods (*id.*). In his study of Wood Turtles in Pennsylvania, Strang (1983) found that numbers of large invertebrates (> 1 cm) per plot increased with litter depth.

Slug densities and land snails are positively correlated with the presence of coarse woody debris (Kappes 2006, Caldwell 1996). "It thus may be expected that slugs, especially the stenoecious forest species, are highly sensitive to climatic fluctuations originating from canopy gaps or from disturbance of the leaf litter layer." (Kappes 2006)

Herbaceous plants are significant ecological components of eastern forests (Whigham, D.F. 2004, Gilliam 2007). They can be harmed directly by logging that alters site conditions and indirectly by edge effects that allow invasion by exotics and other harms (*e.g.*, alteration of microclimate and microhabitat conditions). Recovery from these harms can take many decades (see, *e.g.*, Duffy and Meier 1992, Primack and Miao 1992, Matlack 1994a, Meier *et al*. 1995, Bratton and Meier 1998, Bellemare *et al*. 2002, Vellend, M. 2004, Kahmen and Jules 2005, Vellend, M. *et al*. 2006). For example, in New Hampshire beech-maple forests, "old-growth floras were found to be significantly richer in total, herbaceous, woodland herbaceous, and unique herbaceous species (species occurring only in one forest type or the other)." (Teeling-Adams 2005)

Various mushroom species are important elements of the Turtle's diet (see, *e.g.*, Strang 1983, Kaufmann 1992, Compton *et al*. 2002, Krichbaum pers. obs.). In addition to log size, macrofungal and myxomycete fungi richness was significantly positively correlated with amounts of CWD at old age oak and mixed mesic forest study sites in Ohio (Rubino and McCarthy 2003). Similarly, in New Hampshire all sites with above average coarse woody debris cover had above average numbers of species of macro-fungi, with mean mushroom diversity in old growth sites being 2.5 times the amount in non-old growth sites (Van de Poll 2004).

Intensive even-age logging operations have moisture and temperature effects (Chen *et al*. 1999 and Zheng *et al*. 2000) The operations result in drying and/or increasing the temperatures of the ground surface, as well as compaction of soil. This can alter the habitat of as well as destroy or diminish invertebrates living there, such as slugs (as well as vertebrates such as Coal Skinks and salamanders). Microclimatic differences directly determine the distribution of species within patches and the movement of species among patches (Chen *et al*. 1999). Small Wood Turtles have been found to be more vulnerable to evaporative water loss than similarly sized Box Turtles (*Terrapene carolina*) (Ernst 1968). In some places Wood Turtles are often associated with somewhat more mesic forest habitat conditions (Strang 1983).

Part of the problem with proper management trajectories for Wood Turtles may involve how so-called "early successional habitat" (ESH) is defined or conceived. Some agencies/entities are excessively focused on the early successional habitat that results from timber sales; in other words, the high stem density regeneration that comes up after even-age logging operations. But there is much more to esh than just the saplings that come up after logging operations.

There are many types of esh that are not fabricated by logging. Early successional habitat includes grasslands, shrublands, and young forests that originate after a disturbance (fire, flood, wind, or logging) or where conditions such as thin soils, regular flooding, or exposure to wind support the growth of herbaceous and shrub vegetation and preclude or diminish the growth of large trees. Among the many names that have been given to the landscapes that fall within the early successional category are thickets, grasslands, sapling-seedling stands, heaths, young forests, pole timber, shrubland, and ruderal habitat. A great deal of such habitat is scattered across the forested landscape as a result of tree deaths, blowdowns, hurricanes, ice storms, droughts, Beaver impoundments, edges, or inherent site conditions. These habitats can also be of anthropogenic origin, for example in the form of maintained "game openings", old homesteads, or utility corridors.

But there is a substantial qualitative difference between esh such as a "game opening" (with grass and/or such woody vegetation as Autumn Olive) and regenerating logging site. The benefits to some wildlife from the logging-fabricated esh are short-lived. After the ostensibly beneficial phase (perhaps 10 years) comes a phase where the recovering cut-over sites are admitted to be of little use to wildlife. This 'biological desert' phase (the so-called "sapling" and "pole timber" stages) persists for decades until some beneficial conditions of maturity arise. The USFS admits these early seral sites "provide minimal benefits in regards to herbaceous undergrowth and bugging areas for wildlife." (Jefferson National Forest FEIS 3 - 108)

These high stem density sites are shaded over and typically have little herbaceous or other cover (see Fig. 5). My experience with summer habitat use by Wood Turtles in VA and WV is that their use of such regen areas is minimal (one female in a 3-year old modified clearcut). Nor did I ever found them in the edge habitat alongside the 8km long road at the VA study site. I have, however, found them in small grassy/shrubby game openings and at a grassy abandoned homestead (Krichbaum unpub. data). Their association with natural forest canopy gaps was discussed previously.

My radio-tracking work in VA and WV indicates that Wood Turtles avoid even-age logging ESH regeneration sites (see Fig. 1). Except for the one adult female, who went about 25m into a 3-year old modified-shelterwood cut to eat Blackberries, all the other Turtles only went into the very edges of cut units (10m or less), and these were found at "leave tree" sites (where a mature tree was left standing at the periphery of a cutting unit and the ground floor around it left intact) (some of the points at the north end of Fig. 1 that appear to be in ESH were actually in a part of that stand that was actually not recently logged) (Krichbaum, unpub. data). This comports with the radio-tracking work conducted by Dr. Akre in Virginia that indicates the Turtles tend to avoid recently logged areas (see information in Akre and Ernst 2006). As another example, in Maine the Turtles are considered to not use regeneration sites of the forest-types they inhabit (see Bryan 2007 at pg. 62).

Assessment of proper Wood Turtle management practices must differentiate between the various types of early successional habitat and recognize the difference in habitat quality between regenerating even-age management stands and small grassy or shrubby openings.

My work in VA and WV forests indicates that Wood Turtles prefer sites with a somewhat more open canopy compared to that randomly available (see metrics for "Canopy" and "Canopy gap" at Table 2). Unlike Box Turtles, however, I never found them sitting out in the open in roadbeds or the road edge. These broken canopies or canopy gaps are in otherwise intact forest.

Ernst & Lovich (2009) allude to the effect that, "…areas with openings in the stream-side canopy form the best habitat for wood turtles." However, there is nothing more <u>closed-canopy</u> than regenerating even-age logging sites. And they stay this way for decades. This corresponds to the stem exclusion and understory reinitiation stages of stand development (Oliver and Larson 1996). My examination of regenerating early successional forests in VA found a mean amount of canopy openness (measured with a spherical densitometer) to be 12.23%, in contrast to mature sites with a mean of 15.79%; the measurement for esh is misleadingly high because it includes measurements taken at open leave tree sites at the edge of recently logged sites).

Canopy openings in a forest naturally develop over time (Franklin *et al.* 2002). For instance, for researchers in the Adirondacks, "[v]isual inspection of hemispheric photographs supported our interpretation of patchy canopy structure over old-growth streams; a more homogeneous, closed canopy was characteristic of our mature riparian sites. . . . Light variability is related to the high frequency of canopy gaps typically found in old-growth northern hardwoods (Dahir and Lorimer 1996)." (Keeton *et al*. 2004)

An apparent rationalization for logging decisions in Wood Turtle habitat is the presumption that the Turtles who survive the logging operations will use the "openings" fabricated by the intensive cutting. However, the cutting sites would not be openings, at least not for very long, but would very soon be thickets. The cutting implemented/ proposed/allowed at Wood Turtle sites on a place such as the GWNF (*e.g.*, modified shelterwood) is no different from that proposed elsewhere to fabricate high stem-density thickets for the benefit of species such as Ruffed Grouse (*Bonasa umbellus*). The cut-over sites are soon so densely shaded that they would be of little or no value as nesting, basking, or foraging sites for Turtles. Such cutting sites may function as "openings" for birds or even Deer. But for a creature that basically lives its life four inches off the ground such as does the Turtle these areas do not function as openings in any real sense of the word.

A typical rationale used for timber sales/wildlife management is the assertion that the logged sites will be used by wildlife due to their having increased berry or soft mast production after cutting. However, this so-called "enhancement" is only short-term (2-9 years) (see "for two years" in GWNF 2008 Lee RD Laurel Road EA-34); then the cutover sites have a very long period (30-60 years) of very low soft mast production (Reynolds-Hogland *et al*. 2006) or herbaceous cover (Meier *et al*. 1995). The rationale underlying this current and proposed continuance of a trade-off in a purported short-term "improvement" for long-term harm/degradation to Turtles or Turtle habitat must be fully and fairly evaluated.

In addition, the spatial scale at which openings are perceived as Turtle habitat and the scale at which openings are anthropogenically fabricated can easily be incongruent. This is an important issue in need of thorough consideration. By this I mean: If Turtles prefer forest habitats with an average canopy openness of 20%, that does not translate into managing a 500-acre tract of Turtle habitat by clearcutting 20% of it. And even individual clearcuts can be (and typically are, in my experience in eastern USA forests) far larger than the typical activity area or home range of a Wood Turtle.

For instance, the mean size of the summer (their time of greatest dispersion) activity areas of 65 Wood Turtles I radio-tracked in VA and WV was *ca*. 2 hectares (Table 2), but the typical size of even-age cutting units on the GWNF is *ca*. 10-15ha (they may be far larger on private lands). Cuts such as these have taken place at known occurrence locations of Wood Turtles on the GWNF (*e.g.*, the Paddy, Sours Supin, and Laurel Run timber sales).

Within the Turtle's range, the issues and situations discussed in the preceding paragraphs are certainly not confined to the GWNF. The crucial importance of issues of scale (Levins 1992) must be thoroughly considered in decision-making regarding the Wood Turtle.

The difference in scale of perception of habitat between Turtles and humans may be part of the problem. Perhaps this underlies a common failing in management (not just as regards Wood Turtles): The belief that if a little is good then a lot must be better. Wood Turtles are commonly observed in and around tree-fall canopy gaps in mature forest (Remsberg *et al*. 2006, Akre and Ernst 2006, and Krichbaum 2009 & unpub. data). So then, the reasoning goes, if small canopy gaps are good, then a 5-40-acre logging cut must be even better (*e.g.*, more early successional habitat and edge habitat are provided). However, evidence and reason do not validate this management trajectory.

Bowne (2008) refers to this "potential mismatch between the perception of cover by turtles and humans. . . The grain of a turtle's perception of the landscape (Turner, 1989) is far smaller than I could classify using remotely sensed images." Also see Hamernick (2000) who refers to habitat types that "contain relatively no cover for thermoregulation nor refuge from predators and thus the turtles would potentially not be able to properly regulate their body temperature and would be vulnerable to depredation if they actually spent a significant amount of time in this habitat category."

Burning

Burning ("prescribed" or "controlled") has increased dramatically in eastern forests (see, *e.g.,* 2014 GWNF LRMP and FEIS). Sites with populations of Wood Turtles have been proposed for burning (see, *e.g.*, GWNF Lee RD 2007 Prescribed Burn DM). I do not know the extent of burning of Wood Turtle habitat and occurrence sites tthroughout their range, but it is certainly a significant issue/consern.

Expansive burn projects (of hundreds and even thousands of acres) are proposed that are not confined to fire-dependant communities, but instead include burning of stream-sides, riparian areas, and moist coves (see, *e.g.*, USFS 2007 Lee RD Prescribed Burn). These projects often include the use of heavy machinery and the construction of fire-lines that then provide facilitated avenues for illegal vehicular ingress, invasive species, and predators. Like roads, such lines can also facilitate future human-caused wildfire ignitions.

Many of the concerns and issues expressed above for logging (*e.g.*, microhabitat/microclimate alteration) apply as well to burning of Turtle habitat. Just as with logging, prescribed burning operations may significantly harm Wood Turtles directly, indirectly, and/or cumulatively. As does intensive logging, burning alters the microclimate of the forest floor and alters microhabitat conditions (localized structural and compositional attributes). It serves to simplify niche complexity by removing woody and leafy material from the forest floor. Cover and food used by the Turtles can be destroyed, diminished, or altered. The huge majority of herbaceous flora in eastern forests do not exhibit tolerance/adaptation to fire (Matlack 2013).

And of course Turtles themselves may be incinerated. Wood Turtles at sites previously burned on the GWNF were encountered who had rekeratinized shell mutilations suggestive of long term recovery from burns caused by fire (Krichbaum 2009; Akre and Ernst 2006 observed similar damage). Burns are implemented during the times of year when Wood Turtles are terrestrial (*e.g.*, GWNF Lee RD 2007 Prescribed Burn).

A chief rationale for much of the current and proposed burning is to reduce so-called "hazardous fuels". Much of what is commonly referred to as "fuels", forest ecologists know as woody debris. This material is the dead wood and trees that are essential for and characterize healthy forests. "Fuel" also includes the forest floor litter and humus. All this material is also commonly known as "food', "shelter", or "habitat" for a wide variety of organisms including vascular and nonvascular plants, invertebrates, vertebrates, bacteria, protists, and fungi (McMinn and Crossley 1996). It is an integral part of the compositional, structural, and functional diversity of healthy forests. Fires consume woody debris (Van Lear 1996). Litter amounts can be significantly lower in burned plots (Waldrop *et al.* 2007).

Diminishment, removal, or absence of woody debris, litter, and humus has a dramatic impact on organisms that depend on them for food and shelter, as well as their predators (see McMinn and Crossley 1996). In addition, woody debris contributes to soil fertility and increases moisture retention capacity throughout decomposition. Moisture retaining logs also serve as fire breaks as well as shelter for wildlife should a fire occur. Because of the past and ongoing intensive logging, burning, and other human-caused disturbance that has taken place, there is actually an impoverishment of dead wood ("woody debris" or "fuels") on the great majority of forest sites in the northeast US.

Burning will make sites hotter, drier and more open and exposed (to sun, wind, and predators). The decay process generally tends to mesify microsites while fire tends to xerify microsites (Van Lear 1996). Burns dry out the very conditions upon which the Forest Service has claimed the Turtles depend. Soil moisture is an important abiotic factor affecting the local diversity of soil fauna, such as snails (Martin and Sommer 2004). The incineration of this material (*viz*., woody debris, litter, humus) not only directly destroys many small creatures, but also significantly alters the site quality for a great many other species, such as Wood Turtles and salamanders. For instance, fire can have a negative impact on important components of habitat such as leaf litter, thus degrading mesic micro-habitats (Ford *et al*. 1999).

Prescribed fires are often implemented through ignitions around the perimeter of the burn area. And on top of these multiple ignitions, the interiors of burn sites are also ignited. See, *e.g*., USFS 2007 Lee RD burn project DM-10: "Boundaries of the area may be ignited with drip-torches followed by strips through the interior to complete burning out the area." This project as proposed included burning (down to the streamside) a site known to be inhabited by a population of Wood Turtles. Small and/or slow moving animals have negligible chances to escape when thus surrounded, and even large and/or swift movers can become confused and trapped by a wall of flames that is seemingly in every direction.

Perimeter burns have an even greater chance of killing wildlife of public interest, such as Wood Turtles. The ethical underpinnings for intentionally (even if incidentally) incinerating sentient beings for any reason are certainly questionable.

But it is particularly heinous when the incineration could be avoided or that is unnecessary or that is done simply to achieve some questionable floristic composition that somebody deems desirable.

Roads

Within the Wood Turtle's range there are hundreds-of-thousands (perhaps millions) of miles of roads (Riitters *et al*. 2004). The area ecologically affected by the "road-effect zone" is vast (Forman 2000).

Roads have numerous harmful ecological effects, such as habitat fragmentation and edge effects (Trombulak and Frissell 2000). The physical impacts from roads and road construction include hydrological and microhabitat alteration, chemical run-off and pollution, erosion and sedimentation, obscuration of olfactory or pheromonal cues, and noise and light resulting in modification of animal behavior and movements (Andrews and Jochimsen 2007). These all may serve to destroy, diminish, or degrade Wood Turtle habitat. For example, the species has disappeared from the southern parts of both Ontario and Quebec in conjunction with high road densities (COSEWIC 2007).

In addition, roads also serve to facilitate depredation (Mitchell and Klemens 2000). Further, construction of new access roads may increase the potential for collection of Wood Turtles to occur, as previously inaccessible areas become more readily accessible, and perhaps heavily traveled by outdoors people (COSEWIC 2007). Of course, for Turtles one of the most heinous aspects of roads is the direct mortality from vehicles.

As have others, I have found Wood Turtles killed on roads in VA, WV, and Michigan (Krichbaum 2009 & pers. obs., Akre and Ernst 2006, Ernst 2001a, and Langen *et al*. 2009) (see Fig 3 – this is a small low traffic volume county road through the GWNF). Wood Turtles display the five traits that demographically make an organism most vulnerable to roadkill impacts: slow reproduction, high adult survivorship, non-density dependence, wide ranging, and attracted to roads (such as to nest) (Langden 2009). On top of this are the inescapable facts that the species is small (so not readily noticed by drivers) and slow moving (so unable to avoid vehicles).

The Wood Turtle's habits and habitat, coupled with customary human road placement, serve to exacerbate their vulnerability to vehicular roadkill (*sensu* Roe and Georges 2007). In a New York study, "[r]oad-kill hot spots of reptiles and amphibians are associated with sites that have wetlands within 100 m of the road." (Langen *et al*. 2009) In an Ontario study, turtle road mortality was significantly associated with adjacent open water areas (Ashley and Robinson 1996). In the Wood Turtle's range a disproportionately great many roads are placed within riparian corridors closeby stream and rivers (see Wickham *et al*. 1999, Hudy *et al*. 2004). This fact, coupled with the fact that the Turtles are amphibious and habitually use terrestrial habitat around waterways (not just for nesting), and that they perhaps generally do not use habitat as far from water as do Box Turtles, may place them in incommensurate peril compared with aquatic species or *Terrapene*.

It may be that, like predation from meso-predators, roadkill is having an inordinate impact upon Wood Turtles as compared to many other turtle species. In addition, female Wood Turtles may travel relatively long distances to areas they find suitable for nesting. See Aresco 2005, Gibbs and Shriver 2002, and Gibbs and Steen 2005.

Exacerbating the problem with road kill in general is the gender-biased mortality that can lead to further demographic, reproductive, and recruitment problems. Recent studies suggest that freshwater turtle populations are becoming increasingly male-biased (Gibbs and Steen 2005). A hypothesized cause is a greater vulnerability of female turtles to road mortality with populations tending to be male-biased in areas of high road density (Steen and Gibbs 2004). On average, female Wood Turtles have been found to travel significantly farther from water than males (Tuttle and Carroll 2003, Foscarini and Brooks 1997, Jones 2009). For example, in Virginia the mean of terrestrial female locations was 110.2m, while for males it was 63.8m; in West Virginia the female average was 81.6m, while that for males was 56.2m (Krichbaum unpub. data). If then on their nesting and other perambulations female turtles are more likely to cross roadways than are males, this may signify eventual population declines as females are differentially eliminated (Steen *et al*. 2006 – see Wood Turtle data at Table 3). In addition, females may seek out roads and roadsides in greater proportion than males because of the roadside's attractiveness as nesting sites. This may raise the cumulative risk of females to road mortality relative to males and would be particularly true for roads located near wetlands (*id*.) Indeed, gravid female turtles were the class most likely to be victims of roadkill in New York studies of highway mortality (Langen 2009).

On top of all this is the fact that some people intentionally kill turtles they see on roads. Ashley *et al*. (2007) found evidence that reptile decoys were hit at a higher rate than by chance, with approximately 2.7% of motorists intentionally hitting them. Particularly for roadways with moderate to heavy traffic volumes, this could be a significant factor.

Aquatic degradation/pollution

Timber harvesting is prominent in many areas within the range of the Wood Turtle, and roads probably introduce the bulk of suspended sediment through erosion from road construction and the sediment-transporting ability of constructed roads. Roads can also cause marginally stable slopes to fail, and they capture surface runoff and channel it directly into streams (Allan 1995). In addition, erosion from roads may contribute more sediment than the land harvested for timber (Box and Mossa 1999). Peak stream flows often rise in watersheds with timber harvesting activities, due in part to compacted soils resulting from roads, landings, and vegetation removal (Allan 1995, Box and Mossa 1999). The cumulative effects of timber harvest on sedimentation rates last for many years, even after harvest practices have ceased in the area (Frissell 1997).

Increased sedimention, turbidity, and/or nutrient loads from erosion are known to reduce dissolved oxygen levels (Henley *et al*. 2000). Oxygen levels may be a critical variable for Wood Turtle survival during winter dormancy (Ultsch 2006; Graham and Forsberg 1991; Greaves and Litzgus 2007 & 2008). Increased sedimentation has pervasive effects on lotic food webs and begins at primary trophic levels (Henley *et al*. 2000). Increased turbidity may be the strongest influence on reduced stream invertebrate density and biomass (Henley *et al*. 2000). Further synergistic effects to lotic communities may occur when pesticides or other toxins enter rivers or streams (*id*.).

Tragically, a multitude of waterways within the Wood Turtle's range are polluted or significantly degraded in various ways (*e.g*., fecal coliform, agricultural and industrial chemicals, sedimentation, and acidic deposition). See, *e.g*., Jones, K.B. *et al* 1997.

For example, in Virginia more than 1,300 miles of rivers and streams in the Shenandoah watershed (wherein lies the Turtle's range) fail to meet federal clean water standards because of excess nutrients, sediment, and other pollutants (see http://www.americanrivers.org/site/PageServer?pagename=AMR_MER2006). Virginia's recent water quality report, approved October 16, 2006 by the EPA, identified numerous "impaired (category 5) waters" in the "Potomac River and Shenandoah River Basins", the watersheds where the Turtle resides in the state (see Virginia DEQ 2006). The impairments included approximately 43 impaired waterways within or immediately downstream from the GWNF. Specific indicators for waterways being designated "impaired" include unhealthy populations of macro-invertebrates (poor water quality), fecal coliform, high temperatures, low pH, low dissolved oxygen levels, PCBs, and mercury contamination. Alarmingly, the North and South Forks of Virginia's Shenandoah River suffered massive fish kills in 2004 and 2005 (see http://www.purewaterforum.org/fishkill/index.php). Thus far the reasons for these kills have not been established, but many suspect agrochemicals and runoff from factory farms. The extent of the effects of such events upon Turtles and other reptiles and amphibians are unknown.

The Mid-Atlantic Highlands Streams Assessment ("MAHSA") looked at stream condition across the Mid-Atlantic Highlands (includes all of West Virginia, most of Pennsylvania, and half of Virginia, as well as Western Maryland). Numerous streams in this area could, did, or still do support Wood Turtles (see watersheds in Jones and Willey 2015). Sampling was done in partnership with the mid-Atlantic States, the U.S. EPA Region 3, the U.S. EPA Office of Research and Development, the U.S. Fish and Wildlife Service, multiple universities and private contractors. Half of the streams had fish communities in poor or fair condition. For example: "In Pennsylvania, the miles of streams in poor condition was 27% using both fish and insects; the miles of streams in good condition was 25% based on insects and only 14% based on fish. -- Stream-side habitat alteration and channel sedimentation were associated with 21% and 19% of the stream miles, respectively, in Pennsylvania. Mine drainage, acidic deposition, and fish tissue contamination were associated with about 15% of the stream miles." (US EPA 2000)

In a study of the Chesapeake basin of Virginia and Maryland, "The basin-wide model classified 39% of all first to third order streams in the Chesapeake drainage in good condition, 16% in fair, and 46% in poor." (Maloney *et al*. 2008)

"Agriculture and abandoned mines currently are the two largest contributors to non-point source pollution in the state [of Pennsylvania] (Arway 1999; PADEP 2001). Eutrophication of the Chesapeake Bay has been, in part, attributed to upstream pollution. Acid mine drainage, in particular, has been identified as a significant natural resource issue at several facilities in ERMN (Marshall et al. 2004)." (Rentch 2006)

Many riverine turtles nest on exposed sandbars (Moll & Moll 2004). Due to dams and water releases, significant hydrologic changes occur during the summer nesting season in southern Minnesota, resulting in flooding (and thereby loss of viability) of sandbar nests (Lenhart *et al.* 2013). The anthropogenic hydrologic changes also result in a decline in the number of days of exposed sandbar conditions (suitable for nesting) and may also cause delay in nesting with subsequent late-season emergence and loss of viability. Further, saturation of sand reduces temperatures and thereby inhibits development and reduces survival. These conditions created a trap for some sympatric species (Map (*Graptemys. geographica*), Painted (*C. picta*), and Softshell (*Apalone mutica*) Turtles), but not others. The authors believed that Wood Turtles (*G. insculpta*) here, because they nested higher up on stream banks, were less susceptible to hydrologic change in the rivers. This contrasts with a site inhabited by Wood Turtles in Iowa where agricultural practices have altered stream flows. There, flooding or predation destroyed all nests observed during the course of a study (Spradling *et al.* 2010).

Problems such as discussed in this section above are repeated throughout other states and regions in the Turtle's range. The direct, indirect, and cumulative impacts must be fully and fairly considered in the listing analysis/evaluation. Much of the attention given to water resource protection focuses on riparian areas (Wenger 1999). With regard to Wood Turtles, this is not sufficient as the damaging effects do not necessarily arise from and are not limited to narrowly defined riparian areas (see Sterrett *et al.* 2011). Conservation and management must address non-riparian uplands and entire watersheds (at multiple scales/orders), not just riparian areas. For instance: "Our data suggest that in small stream ecosystems, a simple buffer zone of forested habitat is insufficient to maintain the stream conditions that support high salamander abundances. Instead, we found that salamander abundance was most closely related to the amount and type of disturbed habitat within the entire watershed." (Willson and Dorcas 2003)

Agriculture

At some places, depending on the type, scale and intensity of such operations and other site-specific factors, Turtle populations co-exist with farming (see, *e.g.*, Kaufmann 1992a, Akre and Ernst 2006). Adults and hatchlings may use cornfields (Castellano *et al*. 2008) and hayfields (Tuttle and Carroll 2005). However, significant Turtle mortality and mutilation can occur through the operation of heavy machinery, including mowing, haying or harvesting operations that cut too close to the ground (Saumure *et al*. 2007, Saumure and Bider 1998, Tingley *et al*. 2009, Erb and Jones 2011).

Injuries and deaths caused by farm machinery have been reported for adult *G. insculpta* at study sites in New Jersey (Castellano *et al*. 2008), Virginia (Akre and Ernst 2006), and Nova Scotia (Tingley *et al*. 2009). A study in Quebec indicated that agricultural practices resulted in reduced growth rates and recruitment as well as increased adult mortality (Saumure and Bider 1998). "[A]gricultural activities at our site reduced survivorship of adults by 10-13% and of juveniles by as much as 18%." (Saumure *et al*. 2007) Moreover, Daigle and Jutras (2005) reported significant decline of the Wood Turtle population at this agricultural site. Researchers observed a 50% decline in the number of Wood Turtles at this agricultural site over a seven-year period (Daigle and Jutras 2005; Saumure *et al*. 2007). Significant annual mortality (13.4%) due to agricultural mowing was reported in Massachusetts (Jones 2009b). "Of the seven segments for which I obtained multiple estimates, three showed a significant population decline (within 1 SE) during the study period. Two of these segments lie along the same stream in Hampden and Hampshire Counties, Massachusetts, and exhibited adult mortality rates in excess of 10% annually due to agricultural activities such as plowing, crop dusting, pasture mowing, and field conversion." (Jones 2009)

The Turtle mortality and mutilation that occur through the operation of heavy machinery, especially mowing, haying or harvesting operations that cut too close to the ground, can be significantly reduced by simply raising the mowing height several inches or by using sickle bar mowers (Saumure and Bider 1998, Saumure *et al*. 2007, Tingley *et al*. 2009, Erb and Jones 2011). This increase in cutting height can actually increase annual yield and profitability (Saumure *et al*. 2007). It is advised that cutting and harvesting operations be foregone until the Turtles are inactive and/or in their aquatic phase (Castellano *et al*. 2008).

Overall development and human population growth

The ubiquity of this assault is obvious and supported by myriads of data (see, *e.g.,* Woolmer *et al*. 2008 and Sanderson *et al*. 2002). For example, the region of the Wood Turtle's range is expected to "show substantial increases in developed area, with increases in population and personal income as key drivers." (Alig and Plantinga 2004) Projected losses in forest area by 2030 are 3.0 million acres for the Northeast and 1.2 million acres for the Lake states (*id*.).

See "Footprints on the Land: An Assessment of Demographic Trends and the Future of Natural Resources in the United States," H. Ken Cordell and Christine

Overdevest, principal authors ("hotspot" maps available at www.srs.fs.usda.gov/trends/hotspots.html). Forecasts for dramatic increases in housing density in Virginia and the northeast generally by 2030 illustrate similar pressures. See housing density maps by SILVIS Lab, Dept. of Forest and Wildlife Ecology, Univ. of Wisconsin – Madison, available at http://silvis.forest.wisc.edu/housing.asp .

For instance, in northern Virginia the human population of the North Fork of the Shenandoah watershed (the hydrologic unit wherein lies much of the Turtle's range in Virginia) increased by 53% between 1970 and 1990 (see Jones, K.B. 1997 at http://www.epa.gov/maia/html/la3-humans_land.html#humanuse). The counties to the east of this area that are closer to Washington DC (*e.g.*, Fairfax and Arlington) have experienced even greater development pressures.

A place of rapid population growth, New Hampshire's population grew by 17% between 1990 and 2004, twice the rate of other New England states; it is expected to increase by 180,00 new people by 2030 (Sundquist for the Society for the Protection of New Hampshire Forests 2005/2010). Previously undeveloped land is being subdivided and developed to meet growing demands for housing and services at a rate of nearly 6,900 ha per year. n

In Wisconsin: Development pressures in the state are high and increasing, especially on the shorelines of lakes and streams (Laas 1996). "The number of houses increased by 353% between 1937 and 1999. Ripley's K test showed that houses were significantly clustered at all time periods and at all scales. Due to the clustering, the rate at which habitat was lost (176% and 55% for 100- and 500-m buffers, respectively) was substantially lower than housing growth rates, and most land area was undisturbed (95% and 61% for 100-m and 500-m buffers, respectively). Houses were strongly clustered within 100 m of lakes. Habitat loss was lowest in wetlands but reached up to 60% in deciduous forests." (Gonzalez-Abraham *et al*. 2007)

Urban sprawl has been identified as a significant ecological process causing forest loss and fragmentation in the Chesapeake Bay drainage region and the state of New Jersey (Wickham *et al*. 2007). In the years between 1984-1995 net forest loss was 4.3% in New Jersey; net forest loss of 5.1% occurred in the Chesapeake Bay region in 1992-2001 (*id*.).

"Urban sprawl has been identified as a serious threat to forests and other natural areas, and public concern over impacts has grown in recent years (Bengston et al. 2005). The Southern Forest Resource Assessment (Weir and Greis 2002) found that urbanization has the most direct, immediate, and permanent effects on the extent, condition, and health of southern forests. Although the region encompassing ERMN [Eastern Rivers and Mountains Network] has not seen some of the same increases in population that other parts of the country have, there have still been problems with sprawl. The five counties surrounding DEWA have experienced some of the most rapid residential development in the United States during the past several decades (250 percent growth during the period 1970 to 1990). Pike County (PA) has been the fastest growing county in Pennsylvania since

1970. Recent estimates indicate local populations have grown by more than 50 percent since 1990.

"Furthermore, these census figures do not include the continuing proliferation of vacation homes in the area, because they are not primary residences. The human population in many area developments is three to six times greater during summer weekends and holidays than during the winter. For example, the year-round resident population of one such development (Hemlock Farms) is about 2,500, but on summer weekends this population swells to over 10,000 (from USGS study plan). Sprawl is particularly critical for UPDE, which has only 30 of a potential 75,000 acres in NPS ownership. At NERI, there have recently been several large suburban housing projects proposed for forest land surrounding the park." (Rentch 2006)

Places next to public lands such as National Forests are highly sought after for residential development (such as a new housing development that sprang up in 2008 on rt. 55 in Virginia next to the GWNF). For instance, "the development of lands around the [George Washington National] Forest are expected to increase substantially . . . This is especially important on the GW since it is projected to have the most area of increases in housing density on adjacent lands of all national forests or grasslands, with projected changes on more than 1.4 million adjacent private rural acres." (USFS GWNF 2008 at pg. 11)

Fracking

The discovery of the Marcellus Shale natural gas deposits has resulted in significant changes in the landscape. The Marcellus Shale formation underlies much of the Wood turtle's range in Pennsylvania and parts of New York, Ohio, West Virginia, Maryland, Virginia and Kentucky -- an area that already has a lot of infrastructure for oil and natural gas. This has precipitated an expansive and intensive drive to exploit these reserves (Mufson 2009a, CHPNY Compendium 2014).

The Pennsylvania DEP issued 2000 gas drilling permits in 1999, but was on track to approve more than 8000 in 2008 (Times Herald Record of November 18, 2008). The thousands of new fracking sites have necessitated extensive forest clearing and road building.

Perhaps even more alarming is that the hydraulic fracturing process by which natural gas is extracted from the earth requires millions of gallons of water per site, as well as the use of hazardous chemicals (Mufson 2009b). Right now, much of that water is likely to come from Pennsylvania's and other states' rivers and streams. And after this water is used in the extraction process, it is expelled as chemical-ridden wastewater. It's anyone's guess how it will be disposed as limited facilities currently exist to handle the volume that will be generated. Pollution problems from "fracking" have already occurred in Pennsylvania (Environmental Working Group 2010).

Pennylvania's Allegheny National Forest is an example of the amount of habitat alteration involved with oil and gas development. In the Record of Decision

(ROD) for the 2007 ANF Plan the Forest Service stated that “private oil and gas development has the potential to cause the greatest change to the ANF’s surface resources and environment . . . .” ROD-29. The Forest Service states that approximately 191,000 to 241,000 acres in the ANF are subject to future oil and gas development. Appendix F, FEIS-5. “The ANF has identified an average future projection of 512 new wells per year during the 10- to 15-year Forest Plan period. This would result in an estimated total of 15,680 new wells and 3,122 new miles of private oil and gas roads in 2020 on ANF lands. This would represent almost a doubling of the ANF surface area developed for oil and gas.” Summary FEIS-11.

The direct, indirect, and cumulative impacts of fracking and other energy development upon Wood Turtle populations and habitat must be thoroughly analyzed and evaluated. Fracking operations, including forest modification/fragmentation/reduction and hydrological alteration, can have a multitude of negative impacts upon biodiversity (Kiviat 2013, CHPNY 2014). Even if the drilling does not occur directly upon occupied sites, infrastructure and waste material will serve to further fragment Wood Turtle populations and degrade their habitat.

Biomass

Use of “biomass” (burning trees) to generate electricity is being implemented and promoted throughout the Wood Turtle’s range. The direct, indirect, and cumulative impacts of this exploitation of forests must be fully considered in the listing process.

Using forests for biomass production for use to generate electricity is being touted and promoted as never before (Perlack *et al*. 2005). A suite of policy initiatives, have been implemented to promote biomass, such as from tree plantations and forest and agricultural “waste”, as a source of “renewable” energy. For example, The Forest Landscape Restoration Act, signed into law as Title IV of the Omnibus Public Land Management Act of 2009, authorized $40 million per year to be appropriated into a national fund part of which is to be used to stimulate economic growth resulting from using woody biomass for renewable energy These removals of forest “stocks” and “residues” can lead to significant and widespread reduction and degradation of Wood Turtle habitat and population declines.

US Forest Service analysts estimate that only 3% of the total forest land area in the East is "reserved", or withdrawn from logging by statute or administrative regulation (pg. 26 at USDA FS 2001).

The move to use forests to supply biomass for biofuels is certainly not limited to federal lands. State and private lands will foreseeably be exploited as well.

Massachusetts furnishes an example: “About 80% of Massachusetts’ State forests and parks are slated for logging with only 20% set aside in protected reserves. Aggressive logging and clear-cutting of State forests and parks has already started and new plans call for logging rates 400% higher than historical levels. ‘Clear-cutting and its variants’ is proposed for 74% of the logging. . . . The State has enacted laws and is spending taxpayer money devoted to ‘green’ energy to promote and subsidize the development of at least five wood-fueled, industrial-scale biomass power plants. These plants would require tripling the logging rate on all Massachusetts forests. At this rate, all forests, public and private could be logged in 25 years.” (Matera 2009)

In April of 2009 the state's top environmental official signed off on the 47-megawatt wood-burning power plant project next to the Greenfield Industrial Park with a decision that a broader review under the Massachusetts Environmental Policy Act was not needed (Davis and Fritz 2009).

The impacts to the Wood Turtle from the widespread conversion of wildlife habitat to incinerated biomass must be fully and fairly considered by the USFWS.

Biocides

The effects of herbicides and pesticides on reptiles and amphibians are largely unknown. For example, what are the direct impacts of herbicides upon Wood Turtles? In Virginia the US Forest Service has applied herbicides at locations where the Turtles occur. The “fact sheets” in the USFS project files contain no information on the effect of the herbicides upon Wood Turtles or any other reptile. Relevant issues such as the herbicide’s persistence in the environment, its water solubility, and its effects to non-target organisms were simply ignored in the disclosure.

There can be little doubt that situations such as the above example occur on a daily basis throughout the Turtle’s range.

Immunosuppressive effects of low-level exposure to organochlorines have been implicated in pathologies observed in Eastern Box Turtles (*Terrapene carolina carolina*) (Tangredi and Evans 1997). Researchers found that Map Turtles (*Graptemys ouachitensis* and *G. pseudogeographica)* “deriving from atrazine-treated eggs had a significantly lower success in several of the long-term behavior trials, such as eating ability, time to first consumption, and escape. These findings reveal persistent fitness-reducing impacts on neonatal turtles of atrazine exposure during embryonic development, providing a new perspective on herbicide management.” (Neuman-Lee Biggs and Janzen 2008) And Blanding’s Turtles (*Emydoidea blandingii*), a close relative of the Wood Turtle, in Nebraska were found to be highly susceptible to the pesticide Dieldrin that was applied to cornfields for insect control and accumulated in wetland habitats. Although the use of this pesticide was halted in 1974, the chemical is very persistent in the environment (Congdon *et al*. 2006). Even in a ‘protected’ area, such as a National Wildlife Refuge, PAH (polycyclic aromatic hydrocarbons) contamination can lead to a high incidence of lethal deformities in turtle embyros as well as adults (Bell *et al*. 2006).

Many chemical herbicides used on forests have been documented to mimic the female hormone estrogen (*e.g.*, 2,4-D, 2,4,5-T, atrazine; Colborn *et al.* 1993). These herbicides have also been linked to deformities or mortalities in birds, mammals, amphibians, reptiles, and fish (Hall and Henry 1992, Colborn *et al.* 1993, Berrill *et al.*1994, Berrill *et al.* 1997). "In the absence of studies of any particular chemical which demonstrate that it is not harmful to the species of concern in this HCP/SYP, and in the interest of ecosystem health, the safest approach currently available would be to avoid the use of all of these chemicals." (Welsh, Jr. *et al.* 1998) These researchers were referring to, *Actinemys marmorata*, a close relative of the Wood Turtle; the same approach, however, is relevant and apropos at occupied Wood Turtle sites.

Many biocide applications are associated with agribusiness. At a region-wide scale much Wood Turtle habitat has been taken over by agricultural operations (see Jones & Willey 2015 and Sanderson *et al.* 2002). In many such places (*e.g.*, the Shenandoah Valley of Virginia) the Turtles have been extirpated (Kerr and Deguise 2004, Jones and Willey 2015). For example: "Wood turtles have been adversely affected in the southern parts of Wisconsin by conversion of riparian habitats into agricultural areas. Wisconsin wood turtles are maintaining viable populations in the north, as these areas are not of agricultural value and have been left undisturbed for conservation and tourism." (Brewster 1985)

Isolation/Fragmentation/Population biology

Habitat fragmentation is of great concern to contemporary conservationists (Fischer 2000, Fahrig 2003, Harper *et al.* 2005, Fletcher 2006, Riitters 2007, Eigenbrod *et al.* 2008, Ness and Morin 2008, Marsack and Swanson 2009). Habitat fragmentation negatively affects populations because it decreases interpatch dispersal (Vos and Chardon 1998, Clark *et al.* 1999, Stow *et al.* 2001) and population size (MacNally and Brown 2001, Driscoll 2004, Kuo and Janzen 2004). These effects in turn can lead to a host of genetic problems (*e.g.*, reduced genetic variation and inbreeding) that reduce fitness by decreasing survival and reproduction (Ryan *et al.* 2003) leading to further declines and erosion of genetic diversity, resulting in inbreeding depression (Hedrick and Kalinowski 2000) and a decrease in the time to extinction (Lacy 1993, Brook *et al.* 2002). In fact, habitat fragmentation can lead to catastrophic population declines for species dependant upon dispersal to maintain populations, even if the habitat at particular population sites themselves is undisturbed (Green 2003). Turtles in general are vulnerable to recovery or recolonization problems associated with large-scale habitat fragmentation. Of course, different taxa of turtles respond differently to landscape fragmentation (Rizkalla and Swihart 2006).

The Wood Turtle's evolutionary ability to move across and use the heterogenous landscape is underscored by their locomotor endurance in both the aquatic and terrestrial realms (Stephens and Wiens 2008). There is evidence to suggest a link between the current fragmented distribution of the Turtle and historical disturbance and destruction of habitat within its range (*sensu* Pauley 2008 with regard to the Cheat Mountain Salamander, *Plethodon nettingi*). In other words, the Wood Turtle's current distribution may partially be an artifact of human habitat alteration and disruption.

While the "naturalness" of the Turtle's present sporadic distribution is certainly debatable, this condition is nevertheless currently an empirical fact. Evidence indicates that Wood Turtle populations may be quite localized within its range, with large gaps occurring among populations (Litzgus and Brooks 1996, Ernst 2001b, Amato *et al*. 2008, Willoughby *et al*. 2013, Jones and Willey 2015). Dispersal is currently impeded or hindered within a landscape exhibiting varying degrees of permeability or resistance such that metapopulation dynamics may be affected. Research on Wood Turtles in Ontario indicates that isolation of Turtle populations may lead to lowered hetrozygosity and increased inbreeding (Fridgen *et al*. 2013).

For example, in West Virginia according to a "viability outcome" the Wood Turtle has "low abundance and is distributed as isolated occurrences. While some occurrences may be self-sustaining, metapopulation interactions are not possible for most occurrences." (FEIS, Monongahela National Forest, USFS 2006) The fragmented condition referred to on the MNF repeats itself across the Turtle's range and certainly places the species in a precarious position. Low population numbers in general are problematic, but this concomitant distributional fact exacerbates the Turtle's vulnerability to disturbances or disruptions with the potential to harm their viability. Fragmentation creates isolated subpopulations that, because of their reduced size, have an increased probability of extinction.

In general, the probability of local extinctions is correlated with habitat alterations that sever or attenuate dispersal between local populations (Green 2003). A tenet of island biogeography and metapopulation theories is that island populations can be replenished or "rescued" by immigrants from the mainland or that discrete populations can be rescued by dispersal from other populations (Maschinski 2006). In the instant case there is no mainland to "rescue" the Wood Turtle. Therefore, we must protect local populations and their connectivity as much as possible in order to ensure regional and global persistence.

Protection of known sites of occurrence is not enough. Conservation strategies for metapopulations must consider not only occupied habitat, but also unoccupied suitable habitat and intervening habitat that may be occasionally used during infrequent migration events (Simandle 2006, Huxel and Hastings 1999). Landscape permeability and maintenance of movement corridors are essential to ensure metapopulation dynamics of herpetofauna (Marsh and Trenham 2001). Full protection of extant individual populations/subpopulations is important as it may be that these Turtles serve or may serve as critical source populations that subsidize sink populations at more heavily developed sites elsewhere. Or vice versa (*i.e.*, the Wood Turtle population at a specific site is subsidized by emigration from off-site). In either case consideration of metapopulation dynamics is essential.

Edge-associated turtle nest predation results not only from roads, but also from general habitat fragmentation. Point Pelee National Park in southern Ontario is functionally insularized, isolated by agriculture, residential development, and Lake Erie. The proportion of turtle nests lost to Raccoon predation in 2001–2002 ranged from 63% to 100% among locations in the Park (Browne and Hecnar 2007). The species involved included Blanding's (*E. blandingii*), Painted (*C. scripta*), Spotted (*Clemmys guttata*), and Snapping (*C. serpentina*) Turtles.

Wood Turtles are known to use human-modified habitats such as roadsides and embankments for nesting. This makes them more vulnerable to generalist predators ("subsidized commensals") that have increased in the human-dominated landscape and that regularly use modified habitats and affiliate with edges (see Mitchell and Klemens 2000, Marchand and Litvaitis 2004a). For Painted Turtles (*Chrysemys picta*) researchers found increased predation of nests generally within 30-50 meters of a wooden edge (Kolbe and Janzen 2002b). Use of such anthropogenic sites may also expose nests to unsuitable temperatures (Kolbe and Janzen 2002a).

At present, landscape-scale forest fragmentation characterizes most of the Wood Turtle's range (Riitters *et al*. 2004, Harper *et al*. 2005, Riitters 2007, Tkacz *et al*. 2008); for instance, vast areas of the USA, particularly in the East where Wood Turtles reside, are within 382m of a road (Riitters & Wickham 2003). This condition exacerbates exposure to depredation. Given the amount and scale of habitat and forest fragmentation, most Turtle occurrence locations are within the approximate daily cruising range of many mammalian meso-predators, such as Raccoons and Foxes (*Vulpes vulpes*) (Oehler and Litvaitis 1996). Pedlar *et al*. (1997) found that Raccoon abundance was highest in landscapes with intermediate amounts of forest.

"Nest predator populations are suspected to have increased in many areas as a result of agricultural practices and lower trapping harvest (Congdon et al., 1993; Ernst et al., 1994). The recent conversion of cattle pastures to corn fields, which represent a significant food source for raccoons (*Procyon lotor*), make this hypothesis plausible (Litzgus and Brooks, 1996). An increase in predator population sizes could also reduce juvenile survival." (Daigle and Jutras 1995)

Population biology

Population persistence is constrained by exogenous ecological factors that influence carrying capacity ("K") and endogenous evolutionary and demographic life history traits (Lande 1993, Kinniston and Hairston 2007). The self-sustainability of populations in the long-term is generally a function of population size (Willi and Hoffmann 2009, Reed and McCoy 2014). Thus, the diminishment, isolation, and/or fragmentation of animal populations are clear conservation concerns (Fahrig 2003, Rivera-Ortíz *et al*. 2015).

Typically, a large effective population (N_e) is needed to maintain genetic variation (Frankham 2003, Reed 2005); for example, Fridgen *et al*. (2013) reported lowered genetic diversity in reduced populations of Wood Turtles (*Glyptemys insculpta*) in southern Ontario. The lower genetic variation present in small populations may diminish a species' ability to persist through future environmental challenges (Frankham 2003, Reed and Frankham 2003, Traill *et al*. 2010). This may be of particular concern for taxa such as Testudines, which, due to their generally low genetic variability and reduced microevolutionary rate (Avise *et al*. 1992, Lourenco *et al*. 2012, Shaffer *et al*. 2013), may have limited ability to adapt to the accelerated anthropogenic changes to their environment. Hence, expansive areas may be serving as population "sinks" or "ecological traps" wherein human modifications of the habitat in which populations evolved occur at a rate faster than the populations can adaptively respond (Quintero and Wiens 2013, Robertson *et al*. 2013).

Small, isolated, or declining populations are particularly at risk due to three forms of stochastic influences: genetic, demographic, and environmental (Soulé 1987, Lande 1993, Young and Clarke 2000, Primack 2010). An insidious mutual reinforcement of these biotic and abiotic processes serves to deteriorate population dynamics and collectively drive a population downward to extinction (Fagan and Holmes 2006). In long-lived species such as many turtle species, pervasive deterministic (such as predation or habitat loss) or demographic factors are likely to be greater threats to population viability than are genetic factors (Kuo and Janzen 2004, Pittman *et al*. 2011).

Population declines occur over years, whereas genetic variation is lost over generations. Therefore, particularly in long-lived species, currently expressed genetic signals and status may be decoupled from contemporary demographic status (Marsack and Swanson 2009, Fridgen *et al*. 2013, Willoughby *et al*. 2013). Marsack and Swanson (2009) estimated that "assuming a generation time of 20 years, it would take 100–200 years for *Terrapene c. carolina* to display a mode-shift in their allele frequencies." The generation time of Wood Turtles is even longer, estimated to be 35 years (Van Dijk and Harding 2011).

The viability of populations with old adults can be deceptive. Perceptions and surveys of the distribution and health of present-day populations can be particularly misleading for long-lived species, "reflecting the historical landscape configuration rather than the present one." (Honnay *et al*. 2005, Vellend *et al*. 2006). "Simply examining the abundance of turtle populations may be misleading because of a lag in their response to habitat alterations (Reese & Welsh 1998)." (Marchand and Litvaitis 2004a) The inertial time lag of "extinction debt" may take centuries to express; or put another way, "ghost populations" that are doomed to extinction may take a long time to disappear. Long-lived turtles may persist at high abundances despite decreases in reproductive success or increases in mortality of early life stages that could eventually cause population extirpation (Gibbs and Amato 2000). So a population persisting in spite of such long-term inviability would not be immediately apparent in surveys of adults, due to their long lives and high survivorship (Enneson and Litzgus 2008, Buech *et al*. 1997).

The long generation times of species such as *G. insculpta* and *T. c. carolina* likely also are responsible for misleadingly large effective population sizes estimated from genetic data, being more reflective of the past, before habitat fragmentation occurred (*i.e.*, discrete "populations" in actuality represent independent samples from a larger population reflective of the evolutionary past) (Marsack and Swanson 2009, Willoughby *et al*. 2013). Regarding some Canadian Wood Turtle populations, "urbanization and other human activities dramatically increased in the region around the middle of the 20th century. However, the time elapsed since that increase represents as few as two or three generations of wood turtles. Thus, it is highly unlikely that human-induced bottlenecks have noticeably influenced the genetic diversity of these populations so far." (Tessier *et al.* 2005) Hence, genetic data must be coupled with basic habitat and demographic information, such as population size and trends, for effective conservation and management of threatened species (Avise 1995, O'Grady *et al*. 2004).

The low genetic variability found within the species as a whole means that anthropogenic threats may overwhelm the capacity of Wood Turtles to withstand environmental changes (Amato *et al*. 2008). It is apparent from various surveys and studies that many, perhaps most, of the populations/colonies of Wood Turtles are already very small with low densities (Table 5). Which means their long-term persistence is already at risk (O'Grady *et al*. 2004). Such populations may not at present be robust enough to be considered self-sustaining over the next 50-100 years, at least by the standard of the so-called 50-500 rule (Traill *et al*. 2010).

Over the course of nine years (2006-2014) I sampled Wood Turtles at a forested site on the GWNF in the Allegheny Mountains of northeastern West Virginia USA. Seventy-two individual turtles were found, 32 adult females, 27 adult males, and 13 juveniles. Thirty-two of these (13 adult males, 19 adult females) were recaptured at least once. Using the adult dataset in the program MARK, I estimated population size, lambda, and survivorship with open population Cormack-Jolly-Seber and Pradel models. Estimated adult population size was ~ 77 (33 males and 44 females), with an effective size (N_e) of ~ 75. Annual adult apparent survivorship estimates ranged from 0.8475-0.9479 for females and from 0.8180-0.8916 for males. Estimates of the geometric rate of growth (λ) ranged from 0.8493-1.1689 for females, while those for males ranged from 0.9755-1.020.

The population size estimates here are at the lower end of the spectrum of size estimates generated for other sites in the species' range (see Table 5). The mean estimated population size at ten other locales was ≈ 138. However, some of those estimates included juvenile turtles; mean adult population size at the seven studies that did not include juveniles was ≈ 118. In addition, the estimated population size of 77 for the site reported here is the median value for the eleven cited Wood Turtle studies. That different methods were used to generate estimates, such as Lincoln-Peterson or Schumacher & Eschmeyer, must also be considered when comparing values.

As expected, since Wood Turtles are long-lived organisms and the overall duration of this study was relatively short, models with constant adult survivorship were well supported (Krichbaum unpub. data). Congruent with other studies of freshwater and terrestrial turtles, the turtles here display high annual survivorship (> 0.8), though the survival probabilities generated by the CJS and Pradel models appear to be somewhat low, particularly those for males. Survivorships for Wood Turtles (including juveniles and not differentiated by sex) at three different sites in Virginia were estimated to be 0.921, 0.916, and 0.808 (the second site being most similar to the site reported here and only 4km away) (Akre and Ernst 2006). The annual survivorship estimates reported herein (0.8187-0.8916 for males and 0.8475-0.9479 for females) are somewhat in the midrange of estimates reported for other non-marine chelonians.

Assuming the calculated survival estimates accurately reflect this Wood Turtle population's status and trend, it is not clear whether this somewhat low annual survivorship is problematic for population stability or persistence. For an apparently declining North Carolina population of the congener Bog Turtle, *G. muhlenbergii*, Pittman and colleagues (2011) estimated adult annual survival at *ca*. 0.89 (SE = 0.018, 95% CI = 0.853-0.924). For a Canadian population of Spotted Turtles, *Clemmys guttata*, Enneson and Litzgus (2008) concluded that annual adult survival of less than 0.934 resulted in population decline.

Though the annual survival estimates for this Wood Turtle population are somewhat low, most of the multiplicative population growth rates (λ) generated from the same data are greater than 1 for both males and females. However, using the adjusted model selection, in well supported models most of the estimates of λ for both females and males are less than 1 (Table 6), indicating a declining population, or perhaps a "ghost population". A ghost population is one in which adults are surviving from year to year, but there is insufficient reproduction and/or recruitment to maintain population viability (Vellend 2004). Combining the estimates of the top unadjusted and adjusted models for males and females (geometric means of nine values) returns λ values of 1.0226 and 1.0069 respectively, indicating population growth.

In addition, recruitment may be taking place, as suggested by the presence of thirteen juvenile turtles that were not included in the estimates of demographic metrics. So, this may be a growing, albeit small, population of Wood Turtles. However, even with an overall λ estimated to be greater than 1, populations may still decrease in size over time due to variance in the actual yearly rates (Converse *et al*. 2005). It is difficult to be sanguine about this population or any other small population of Wood Turtles that may be living at the razor's edge of viability (Reed and McCoy 2014).

This species is long-lived and apparently has low recruitment, so evidence of declines (or mortality) may not be readily apparent. In general, demographic characteristics such as low population density, low juvenile abundance, low survival, or skewed sex ratios may portend unstable or possibly declining populations (Nazdrowicz *et al*. 2008). Perhaps the simplest evidence of a stable population of turtles such as these is an age structure with significant proportion of individuals in younger age classes (see Reese and Welsh 1998).

Very small populations of long-lived organisms may nonetheless be considered to be viable populations for short time periods. Demographic modeling by Shoemaker *et al*. (2013) on New York Bog Turtles indicated that colonies with as few as 15 breeding females had a >90% probability of persisting for >100 years. Clearly, even somewhat small populations such as reported herein could be valuable conservation reservoirs and restoration nuclei, for instance, by providing for demographic and genetic exchange as well as facilitating range shifts in response to climate change (Shoemaker *et al*. 2013 & 2014). Wood Turtles' long lives also afford us a cushion of time for implementing strong conservation and recovery measures.

Enneson and Litzgus (2008) studied the demography, life history, and **elasticity** of the Spotted Turtle (*Clemmys guttata*), a close relative of the Wood Turtle. Their findings are relevant to the instant case: "Elasticity in population growth rate is the proportional change of the rate of population growth in response to a proportional change in a matrix element (de Kroon et al., 1986). It can be calculated analytically, giving the response of the growth rate to very small changes in elements of the matrix (de Kroon et al., 1986). Thus, stage-classified modeling has the potential to determine to what extent changes in vital rates will affect population size, growth rate, and persistence . . .

"Similarly, results of perturbations to parameters indicate that small changes in adult survivorship result in large changes to population growth rate (Fig. 1, Table 2), unless adult survivorship is already low, and that very small decreases in survivorship could potentially lead to a declining population. The finding of highest elasticity in the adult life stage is nearly ubiquitous in demographic analyses of turtle populations (e.g., Doak et al., 1994; Chaloupka, 2002; Blamires et al., 2005), with the exception of loggerhead sea turtles and desert tortoises, for which juveniles or subadults have the highest elasticity (Crouse et al., 1987; Heppell, 1996, 1998). Similarly, simulations in turtle species with similar life histories to that of the spotted turtle have shown that small increases in adult mortality may cause serious declines in population sizes, or that small decreases in adult mortality can result in reversal of declines (Crouse et al., 1987; Congdon et al., 1993, 1994). This was consistent with our finding that only a 3% decrease in adult survivorship could cause decline in spotted turtles (Table 2). . . .

"**Given similarities in life history, it is likely that our results for spotted turtles can be applied to many other freshwater turtle species, including the numerous species that are considered at risk and in need of recovery action** [emphasis added] . . .

"Stage specific modeling allows prediction of the potential success of conservation actions that target various life stages. For turtles, these conservation actions typically include protection of nests, captive hatching and rearing of hatchlings, also known as ''headstarting'', and increasing protection of adults from threats such as road mortality, habitat destruction, and collection for the pet trade. .

. . Conservation efforts for spotted turtles should focus on preventing adult mortality by reducing threats." (Enneson and Litzgus 2008) The Wood Turtle's life history traits indicate the same.

In another turtle species with similar age of maturity and reproductive output (Blanding's Turtle (*Emydoidea blandingii*)), increases of 5% in rates of adult mortality lead to population declines, whereas an annual mortality of 70% of eggs can be tolerated, all else being equal (Congdon *et al*. 1993).

Compton (1999) "built a simple demographic model to estimate the effect of the annual removal of a small number of adults from a hypothetical population of wood turtles. The model indicated that removal of a single adult annually from a stable population of 100 adult turtles would cause a 60% decline in over 100 years, and that removal of two animals annually would extirpate the population in less than 80 years."

The problems are acute in Wood Turtle populations. Not only do they exhibit low annual egg production and high mortality of young, they also do not reach sexual maturity until an advanced age, on average 14-18 years old (see, *e.g.*, Akre 2002, Brooks *et al*. 1992). Reed and Gibbons (2003) examined the elasticities of a range of North American freshwater and terrestrial turtle species. Their research shows that, of all North American turtle species, Wood Turtles specifically are among the most sensitive in this regard. In other words, population persistence for this species is extremely sensitive to the loss of individuals of either adults or juveniles. The implications of this relevant factor are striking.

It means that if enough adults are not protected from takings, then populations inevitably collapse. How many can be lost? The loss of a very small number above natural attrition can be devastating, to the point that it is simply not feasible for reproduction to make up for the loss. The Turtles may not reproduce enough or survive long enough to make up for the losses from collection, predation, being killed on roads or by logging operations, or a host of other factors. What density of Wood Turtles is needed for ensuring reproduction and sustaining viability? The "minimum viable population density" is unknown. However, the fewer Turtles, the less the chances of having mating encounters (see Belzer 2000 with regard to Box Turtles, *Terrapene carolina*). This "negative density dependence can cause sparse populations to continue to decline even after the original cause of decline is removed." (Strayer *et al*. 2004)

Curtailment of range

In Pennsylvania alone, over 7000 km of streams are impaired by acid mine drainage ("AMD"). There is only one PA record of *G. insculpta* from an AMD-impaired stream (Williams 2009).

See Jones and Willey (2015) for further evidence of range curtailment.

Recreation

The detrimental effects human recreation can have upon Wood Turtles are well documented. A twenty-year study in Connecticut clearly showed that Wood Turtle populations may suffer from increasing recreational use (*e.g.*, hiking and fishing); the two discrete study populations declined by 100% in ten years (Garber and Burger 1995). The possible mechanisms of decline include removal by recreationists, road kill, handling by recreationists, increased number of predators attracted by food waste, and disturbance by dogs. These types of recreational impacts are not special to Connecticut; they are undoubtedly repeated elsewhere across the Turtle's range (Wusterbarth 2000).

From my personal experience on dozens of fishing trips with my father when I was a kid there was an unwritten rule: If you see a turtle, catch it. And if your parents let you, take it home. I think this still holds true today for many families.

The expanding operation of ATVs (all-terrain vehicles) and OHVs (off-highway vehicles) in sensitive habitats is a growing problem all over the country. In addition to illegal trespass, numerous areas in the Turtle's range are open to legal ATV and/or OHV use.

ATV and 4-wheel-drive vehicle traffic have been implicated in Turtle population declines in Canada (COSEWIC 2007). This occurred from Turtles being run over, nests destroyed, and Turtles picked up or deliberately killed.

I have observed ATV usage and evidence of their illegal trespass in areas inhabited by Wood Turtles in Virginia and West Virginia (Krichbaum pers. obs.). This includes the operation of such vehicles actually in the stream channel occupied by the Turtles.

According to a report released by the US Forest Service, the number of off-highway motorcycles and all-terrain vehicles rose from about 2.9 million in 1993 to about 8 million in 2003, an increase of 174 percent. OHV sales more than tripled between 1995 and 2003 to more than 1.1 million. There were perhaps 9.8 million ATVs in the US as of 2008 (Cordell *et al*. 2008). "Between 1996 and 2003, wheeled off-highway recreational vehicle (a.k.a., ATV) registrations in New Hampshire more than doubled for resident and more than tripled for non-resident owners. Similarly, boating registrations doubled between 1980 and 1990 and continued to increase by 19 percent from 1990 to 2000." (NH 4-49)

Cumulative impacts

The nation's populations of Wood Turtles are in a precarious position.

Amphibious Wood Turtles, associated with both terrestrial and aquatic habitats, are hit by impacts from multiple human induced stressors. Of great concern are the cumulative impacts of all the stresses upon Wood Turtles, *e.g.*, roadkill, collection, depredation, climate change, habitat destruction/degradation/fragmentation, small populations, air/soil/water pollution.

The USDA Forest Service and others have rationalized prescribed burning and other habitat alterations of Wood Turtle habitat with the assertion that the species is “adapted to fire” or is somehow “tolerant of disturbance”. In the past when populations were much greater and more distributed across the landscape and dispersal was easier, losses due to fire and local disturbances could perhaps be absorbed and recovered. However, the fragmented (“disjunct, isolated” in Bowen & Gillingham 2004), reduced, and declining status of contemporary populations makes assertions of adaptation and resiliency superficial and misleading.

Fossil remains of Wood Turtles have been dated to millions of years old (Harding 2002). Here are a few other things the Turtles were/are adapted to over their evolutionary history: expansive areas of old growth forest with great structural and compositional complexity, ecosystems without thousands of miles of roads and millions of cars, much smaller numbers of meso-predators, ecosystems not overrun with Deer and invasive species, waterways running without pollutants and other impairments, ecosystems with numerous Beavers, Wolves, and Cougars, landscapes not overwhelmed with anthropogenic edge effects and fragmentation, terrestrial and aquatic landscapes with a high degree of connectivity, clean air and a lack of acidic deposition, habitats without millions of recreationists and others who like to collect or harm turtles, and habitats not despoiled by tens-of-millions of people and our industrial, agricultural, commercial, and residential development *ad nauseum*.

It is clear that the Turtles present day environment is far different from that which they adapted to over the course of their evolutionary history. In the face of all this, is it reasonable to inflict our remnant populations of Wood Turtles - populations with questionable viability - with actions bearing the potential to bring them direct, indirect, and cumulative harm? It is not just glib, it is harmful to rationalize away concerns for these actions with the expedient that the Turtles’ are “tolerant” or “adapted” to them.

(b) Overutilization for commercial, recreational, scientific, or educational purposes (Factor B)

Even though various states within the Turtle’s range have enacted some type of protected legislation or designation, collection is ongoing. The Wood Turtle featured prominently in several recent high-profile busts of illegal wildlife sellers by the USFWS and the VDGIF. In the summer of 2008 a poacher was arrested in West Virginia with over 100 wild-caught Wood Turtles in his possession (J.D. Kleopfer, VDGIF, pers. comm. to SK August 2008). Poacher Ellard, owner of a Florida reptile exporting business, had already been busted previously for collecting Spotted Turtles (*Clemmys guttatta*) in North Carolina). Ellard and his associates were charged with violating the Lacey Act and Ellard pled guilty to charges on 31 July 2009 (Hollowell 2010). For his conviction he was sentenced to serve one year of home detention, five years of probation and pay $12,000 in restitution for his participation in the illegal capture and transportation of protected turtles, a violation of the Lacey Act. The sentence meted out to Ellard amounted to little more than a slap on the wrist.

And in March of 2009 eight-teen individuals were charged in New York for the illegal sale of reptiles and amphibians, including Wood Turtles (NYDEC 2009). This poaching activity involved the poaching and sale Wood Turtles via the internet and commercial reptile shows. In addition, New York turtles were being laundered through middlemen in other states (such as Pennsylvania), then getting exported overseas for meat and other uses.

The magnitude and impact of the illegal wildlife market illustrated by the New York bust is significant. "'Our investigators began this operation with a simple question: Is there a commercial threat to our critical wildlife species? What they found was alarming,' Commissioner Pete Grannis said. 'A very lucrative illegal market for these creatures does exist, fostered by a strong, clandestine culture of people who want to exploit wildlife for illegal profit.'" (*id.*)

In August 2015 an Illinois man was convicted in the Eastern District of Louisiana federal court for violations of the Lacey Act regarding the Wood Turtle (see http://www.justice.gov/usao-edla/pr/illinois-man-sentenced-violating-lacey-act, http://annamiticus.com/2015/08/18/louisiana-court-sentences-turtle-trafficker-to-prison/). He attempted to purchase 100 Wood Turtles for $40,000 ($400/Turtle). This individual, Keith Cantore, has a history of illegal turtle dealing.

Actions that take in a very short time-period may have permanent or long-term effects. For example, one population in Ontario was predicted to be extirpated within 50 years, because over only a few days collectors removed about 60% of the adult population (COSEWIC 2007). A turtle researcher in Wisconsin tracked a transmittered turtle to a dumpster and found remains of over 60 other Wood Turtles that had been killed for food by one individual (COSEWIC 2007).

And collection by profiteers is certainly not the only collection that impacts the Turtle. Wood Turtles are so beautiful, bright and active that they are highly desired for pets. Who knows how many are removed from populations by private individuals not to sell, but simply to take home for "personal use". Burger and Garber (1995) stated that humans find Wood Turtles "irresistible" and generally remove them or at least displace them when they are found. The Turtle's apparent intellect (Tinklepaugh 1932) and "striking appearance" (Carr 1952) have certainly boosted its popularity as a pet. Wood Turtles fetch high prices both domestically and overseas. On Kingsnake.com turtle classifieds (http://market.kingsnake.com/index.php?cat=39) pairs of adult Turtles were priced at $500-750 (Hollowell 2010). While in Tokyo, Japan, prices of $3,786 were being asked for individuals (*id.*). Obviously, values such as these are huge incentives for illegal trade.

The export market to Asian countries, particularly to China, has exploded in recent years. Turtles are being vacuumed up in vast numbers for food, traditional medicine, and pets. Turtles in the United States are certainly not immune to this legal and illegal trade (see Hylton 2007). "Demand for turtle meat and their body parts deriving from wild caught turtles has been on the rise in growing Asian communities in Houston, Dallas Fort Worth, Oklahoma City, Atlanta, San Francisco and New York City (S. Haitao, pers. comm. 2007). Chinese turtle dealers frequent online commercial reptile websites and post solicitations to recruit American sources to export "huge number" of freshwater turtles from the United States" (CBD *et al*. 2008). Recently convicted Wood Turtle poacher/trafficker Cantore wanted the turtles for Chinese customers.

Listing under the ESA can be expected to result in harsher penalties meted to criminals, thus serving to significantly discourage trafficking in Wood Turtles.

(c) Disease or predation [along with habitat alteration] (Factor C)

In many places, such as eastern USA, the quantity and configuration of habitat edges (habitat at the periphery of a patch) are largely determined by human-induced disturbances including timber harvesting, agricultural expansion, and urbanization (Harper *et al.* 2005). In many cases, areas influenced by edge effects dominate the landscape (Riitters *et al*. 2004, Harper *et al*. 2005, Riitters 2007). The area of a patch that is unaffected by edge effects (*i.e*., the core or interior) depends upon the size of the patch, the shape of the patch, and the penetration distance of the edge effect (Harper *et al*. 2005, Van Dyke 2008). The distance of edge influence (DEI) is the result of the penetration distance of various environmental variables and gradients (Laurance 2000, Zheng & Chen 2000). For example, in hardwood forests of Wisconsin's Nicolet NF, edge effects on Ovenbird (*Seiurus aurocapillus*) nest success and clutch size extended 300 m into intact forest from recent clearcuts <6 years old (Flaspohler *et al.* 2001), whereas the edge effect on Indigo Bunting (*Passerina cyanea*) nest success identified by Weldon & Haddad (2005) in South Carolina pine plantations was 12.5m and Kolbe & Janzen (2002b) found a 30m DEI for Painted Turtle (*C. picta*) nests in Illinois.

The edge effect typically of great concern is that from predation. Landscape level changes have altered predator abundances and distributions, with consequent impacts on attributes such as nest success (Misenhelter & Rotenberry 2000, Weldon & Haddad 2005). Historically, forest edges were few and disparate enough to prevent edge-affiliated predators from developing substantial populations (Weldon & Haddad 2005). Now, in many cases, areas influenced by edge effects dominate the landscape (Harper *et al.* 2005), with a resultant increase in numbers of small and meso-predators (Browne & Hecnar 2007). The perfusion of these predator populations is facilitated by direct human subsidy and the extirpation of large predators (Mitchell & Klemens 2000). Edge cues are thought to trigger the evolved preference for light gaps arising from dispersed natural canopy disturbances present in wild forests (Gilroy & Sutherland 2007).

At present, landscape-scale forest fragmentation characterizes most of the Wood Turtle's range. This condition exacerbates exposure to depredation upon smaller organisms by the midsized omnivores of concern (Harris and Silva-Lopez 1992). Given the amount and scale of habitat and forest fragmentation, most Turtle occurrence locations are within the approximate daily cruising range of many mammalian meso-predators, such as Raccoons (*Procyon lotor*) and Foxes (*Vulpes vulpes*) (Oehler and Litvaitis 1996). Pedlar *et al.* (1997) found that Raccoon abundance was highest in landscapes with intermediate amounts of forest. Over two decades ago numbers of Raccoons, a species commonly associated with roadsides and other edges, were estimated to be fifteen to twenty times higher in the USA than they were in the 1930s (Sanderson 1988).

Over twenty-five years ago Temple (1987) observed: "Because many of the potential predators on turtle nests are edge-inhabiting species, their densities typically increase in fragmented habitats (Harris, 1984). Furthermore, in a severely fragmented habitat, it may become difficult or impossible for turtles to lay their eggs far from an edge." For instance, vast areas of the USA, particularly in the East where the Wood Turtle and most chelonian taxa reside, are within 382m of a road (Riitters & Wickham 2003) (see Fig. 4). Species vary in life history characteristics and behavioral responses, thus some are more susceptible to negative road or traffic effects than others (Rytwinski & Fahrig 2012). Such effects include both direct vehicular mortality and depredation. These impacts of deleterious edge effects translate to a form of habitat loss for various taxa (Harris *et al.* 1996).

Predation pressure having devastating impacts upon nesting success and subsequent recruitment are reported throughout the Wood Turtle's range (see, *e.g.*, James Harding pers. com. 2007, Siart 1999, Brooks *et al.* 1992, Buech *et al.* 1997b, Hunter *et al.*, 1999, Harding 2002, Paradis *et al.* 2004, and Bowen & Gillingham 2004). For example, in Quebec it was estimated that predators killed 40% of the nesting females at nesting site in a few years (COSEWIC 2007). In some places predation pressure may be the single most important factor affecting the sustainability of Wood Turtle populations.

Due to human subsidy (*e.g.*, garbage), habitat alteration (*e.g.,* increases in ecotonal edges and roads), and extermination of large predators (*e.g.*, Cougar and Gray Wolf), populations of many meso-predators such as Raccoons have markedly increased in the East ("mesopredator release") (Engeman *et al.* 2005; Mitchell and Klemens 2000, Prugh *et al.* 2009). The inflated populations of subsidized meso-predators have had and are having a significant impact on Wood Turtle populations. In addition to nests disinterred and destroyed (*e.g.*, seven seen in one day at a Virginia site – Krichbaum pers. obs.), numerous adult Turtles encountered have limbs, feet or tails missing or shells that appear to have been chewed/gnawed upon (Harding 1985, Farrell and Graham 1991, Ernst 2001a, Walde *et al.* 2003, and Krichbaum 2009). At a forested site in Ontario 60% of adult Turtles observed bore injuries from predators (Brooks *et al.* 1992). Deceased Turtles have been found that had been previously observed alive with large wounds on their limbs (Krichbaum 2009). The proportion of such injuries amongst Wood Turtles appears to far exceed that observed in Box Turtles (*id.*). Harding (1985) recaptured significantly fewer injured Turtles during his study, indicating that long-term survival is compromised. Limb amputations and mortality may result from exposure to predators while overwintering (Walde *et al*. 2003, Carroll and Ultsch 2006).

The predators of concern include Raccoon (*Procyon lotor*), Gray Fox (*Urocyon cinereoargenteus*), squirrel species (*e.g.*, *Tamiasciurus hudsonicus* and *Sciurus carolinensis*), Striped Skunk (*Mephitis mephitis*), Red Fox (*Vulpes vulpes*), Coyote (*Canis latrans*), Opossum (*Didelphis virginiana*), Mink (*Mustela vison*), River Otter (*Lutra canadensis*), Eastern Chipmunk (*Tamias striatus*), and Great Blue Heron (*Ardea herodias*) (Mitchell 1994, Ernst and Lovich 2009).

Raccoons or their sign are commonly seen at National Forest Wood Turtle sites in the Virginias; also seen are Striped Skunks, Opossum, Red Fox, Mink, Coyotes, Chipmunks, and Gray Squirrels (Krichbaum 2009). I have observed Raccoons waiting at a nesting site in VA while female Wood Turtles were laying their eggs. And the affiliation of Raccoons with stream corridors, an important consideration for the amphibious Wood Turtle, is well known (Spackman and Hughes 1995).

Raccoons are frequently implicated predators of turtles; for example: "Raccoons were the most frequent predator of simulated nests in our study area, accounting for 74% of predation by identified carnivores (Marchand et al., 2002)." (Marchand and Litvaitis 2004b) "Our results suggest that predation of simulated turtle nests may be a consequence of their distribution and location relative to the foraging activities of common nest predators, especially raccoons (*Procyon lotor*)." (Marchand and Litvaitis 2004a) "Recruitment problems in Point Pelee [an Ontario Park] are likely occurring because of elevated predation on eggs, hatchlings, and juveniles. Predation by raccoons is most likely responsible, but tilling in agricultural fields adjacent to the park would also destroy any nests in these areas." (Browne and Hecnar 2007) At a gravel-pit nesting site beside a road in Quebec in 2004, Raccoons killed 25% (nine of thirty-six) of female Wood Turtles during oviposition and nest construction (Paradis *et al*. 2004).

Contemporary numbers of meso-predators are likely to far exceed historic levels. For example, over two decades ago numbers of Raccoons, a species commonly associated with roadsides and other edges, were estimated to be fifteen to twenty times higher in the USA than they were in the 1930s (Sanderson 1988). The numbers and distributions of meso-predators now confronting the Turtle are not entirely natural, but instead are a response to various human disturbances and subsidies. Thus far, the impact of management activities on exacerbating depredation has been little addressed by land managers, owners, and developers. This is evidenced by the inadequate or nonexistent buffer zones (as regards Turtle conservation) where intensive habitat alteration is prohibited.

At 12 different sites in VA and WV where I have found Wood Turtles, the sites with the lowest proportion of Turtles with major injuries were the least developed sites. The site with Turtles with the greatest proportion of major injuries (e.g., missing limbs) was the most developed (Krichbaum, unpub. data). At this site there is a paved road, residential development, fishing & hunting, and agriculture.

The abundant populations of generalist predators such as Raccoons indicate that active intervention may be necessary in some areas (Garrott *et al.*, 1993; Congdon *et al.*, 1993; Engemann *et al.* 2005). An alternative approach is to manage landscapes in order to reduce predator impacts (Schneider 2001). In other words, halt the fragmentation of habitat where we can and restore more natural conditions to places that we have developed in the past (*e.g.*, road obliteration and revegetation). Allowing forests to naturally develop over time would be a good general management direction for Wood Turtle core habitat.

Numerous adult Turtles have been observed with what appear to be respiratory infections (runny noses) (Krichbaum 2009). Iridoviruses and upper respiratory tract diseases (Mycoplasmas) are increasingly affecting other turtle populations, including sympatric Box Turtles (*Terrapene carolina*) (see Allender 2007, Johnson 2006, Wendland *et al*. 2004, and Tangredi and Evans 1997; also see "Deadly ranavirus hits box turtles, tadpoles in Montgomery County, Maryland" by Katherine Shaver, Feb. 12, 2012, Washington Post).

I do not know if such pathogens as the above have attacked Wood Turtle populations or if they may attack in the future. We do know, however, of herpes viruses in Wood Turtles (Ossiboff *et al*. 2015). Viruses such as these can potentially result in significant disease.

(d) The inadequacy of existing regulatory mechanisms (Factor D)

The Wood Turtle currently receives no direct Federal protection other than CITES provisions. In certain situations the Lacey Act can also cover the Wood Turtle. Designations such as "Sensitive Species" by the USDA Forest Service do not stop harmful projects from being implemented, as long as the species is "considered" during planning.

As a listed species under the Endangered Species Act, the Wood Turtle would receive substantial protection in the United States. Under the Act, federal agencies are prohibited from permitting, funding, or carrying out actions that jeopardize the continued existence of any endangered species, and have affirmative duties to use their authorities to conserve and recover endangered species. To ensure this occurs, the Act requires federal agencies to consult with USFWS when their actions may affect listed species. These requirements would provide substantial protection for the Wood Turtle.

Existing regulatory mechanisms have been ineffective at preventing the decline of the Wood Turtle and preventing, mitigating, or rectifying many principal threats to the species. Take of and harm to Wood Turtles are ongoing, chronic, and ubiquitous. As the petition and this comment letter detail, harm in the form of poaching, habitat destruction, modification, and fragmentation are ongoing and imminent. Wood Turtles certainly are not always considered in conservation and development planning (Bowen and Gillingham 2004).

For example, the USDA Forest Service uses "categorical exclusions" to avoid thorough, full, and fair consideration of issues involving the Wood Turtle or otherwise fails to adequately analyse and divulge to the public the impacts of management actions upon the Turtle. See attached administrative appeal of a GWNF 2007 controlled burn project.

I, as well as other organizations (*e.g.*, Wild Virginia, Virginia Forest Watch, Heartwood, Sierra Club), tried for years to get the GWNF to give special management protection to some Wood Turtle sites on the GWNF by designating them Special Biological Areas or otherwise strongly protecting them in the revised Forest Plan (see attached 2011 comments submitted to the agency during the Plan revision process, one of dozens of submissions to the FS and state agencies). The Forest Service refused to do this for any of the nine sites to which they were alerted (see Revised GWNF LRMP of 2014). One of the areas (the location of my VA study site) is home to a resident population of Wood Turtles, with well over two hundred adult individuals observed by Krichbaum, Dr. T. Akre, and others in the recent past (Akre unpub. data; see also VDGIF occurrence records). This area and population are perhaps the most important and robust on the entire National Forest. Akre and Ernst (2006) emphasized that it probably represents the best potential for long-term protection of a viable metapopulation of Wood Turtles in all of Virginia. Nonetheless, the USFS refused to grant even this area meaningful protections in the 2014 revised Forest Plan.

The agency's proposals were little more than the codification of business as usual on the Forest. For example, see "CM 6.01 No logging activities allowed within 100 feet (30 m) of the edge of perennial streams and seeps, except to enhance habitat for wood turtles." (GWNF "Draft Aquatic Ecological Sustainability Analysis" of February 2010). This meager "protection" is little more than a typical "riparian buffer" that has been in place throughout the Forest (whether there are Wood Turtles or not) since the 1993 Plan and the adoption of the 1976 NFMA.

In the revised Plan, Wood Turtle population locations are not stringently protected from intensive logging (such as "modified shelterwood"), burning, and road construction, as well as some recreational activities. Wood Turtle population sites are not allocated and protected as "special areas" (*e.g.*, SBAs or RNAs) with their own prescriptions. Further, clear meaningful protections (strong and enforceable Standards, etc.) are not in place to restrict the aforementioned harmful activities from occurring within the Turtles' core habitat (USDA FS GWNF Revised LRMP 2014).

I am not aware of any National Forest or state public lands that give stringent protections to Wood Turtle habitat and populations.

The attenuated streamside buffer zones (the terrestrial habitat 33-100 feet from the stream) normally applied by the Forest Service and others (see, *e.g.*, Phillips *et al*. 2000) are simply inadequate for protecting Wood Turtle populations and their habitat. To somehow "protect" 100-foot buffer zones (or "riparian corridors" or "streamside management zones") barely begins to cover the terrestrial habitat used by Wood Turtles; in other ways it may be insufficient as well for protecting aquatic habitat.

A problem with the management direction for Wood Turtles on the GWNF (see 2014 LRMP at 3 - 10-11), as doubtless with the direction at other places, is the deployment of vague verbiage that can allow all kinds of activities to take place. What precisely does it mean to "manage and protect", "maintain and create openings", "mitigate disturbance from vegetation management activities", or "[s]mall patches of early successional forest may be created"? The spatial extent of these actions and the spatial extent of where such an "approach" is to be applied are unknown. And beyond that ambiguity, what "management activities" are precisely required or prohibited at Wood Turtle population sites? The "Objectives" and "Standards" in the Plan can be construed to allow all manner of activities. Further, EVERY project (regardless of how much logging, burning, or road building is involved) the FS has ever implemented (since 1990) on the GWNF "protects" the forest and the creatures living there; that is what the agency's "Findings of No Significant Impact" or "Categorical Exclusions" officially document (I have monitored hundreds of FS activities for 25 years through their NEPA process). Hence, in the instant case, "approaches" and statements that vaguely confer "protection" to Wood Turtles may amount to little more than business as usual. Although my comments here refer specifically to the GWNF, approaches on other National Forests and management allowed by other states share similar deficiencies (*i.e.*, the lack of strong and enforceable regulations that sufficiently protect Turtles and their habitat).

What is the current status of populations on the National Forests? How many Turtles are currently lost from road kill, collection, and depredation? What is the recruitment into the populations? What density of Wood Turtles is needed for ensuring reproduction and sustaining viability? How many may be lost if a project was implemented? How and to what extent would collection or mortality by Forest recreational visitors be exacerbated by a project? What are the cumulative impacts in conjunction with other stresses upon the population? How many can be lost/killed without significantly harming the viability and sustainability of the affected population(s)?

On all these issues and more the Forest Service and other entities public and private do not have the basic information, yet they charge ahead with projects that may kill still more Turtles or degrade still more Turtle habitat, adding additional stresses to populations. A critical question to ask is how much cumulative harm or mortality can a population absorb and still be healthy and viable for the long term? The agency does not have fundamental information on the Turtles' populations, nor has it conducted population viability analyses (see Reed *et al*. 2003), yet somehow the FS does know that its decisions are having "no significant impact" (see the Decision Notices, Decision Memos, and Findings Of No Significant Impact for numerous projects affecting the Turtle on the GWNF, *e.g.*, the Paddy timber sale). The validity and scientific integrity of such findings are dubious to say the least.

Governmental and commercial entities at various levels cannot or will not adequately protect Wood Turtle populations and habitat. Vague and indulgent approaches are insufficient. Therefore, this species needs ESA protection.

(e) Other natural or manmade factors affecting its continued existence (Factor E).

Studies have shown Wood Turtles to exhibit nest site fidelity, staging behavior (*i.e.*, concentration of females in the vicinity of the nesting site prior to nesting), and an affinity for multiple females to aggregate at a single nesting site (see, *e.g.*, Walde *et al* 2007, Krichbaum 2009, Jones and Willey 2015). As Walde *et al* (2007) point-out, these behaviors intensify the Turtles vulnerability to anthropogenic disturbance, harm, or collection, as well as to non-human depredation.

There is a further problem with clear conservation implications elicited by a Virginia dirt road used as a nesting location: a site may have the physical characteristics favored by the Turtles for nesting, but in fact serve as a population "sink" (Pulliam 1988) or "**ecological trap**" (Gates and Gysel 1978). Traps have been termed attractive sinks, but their dynamics are fundamentally different. Sinks conceptually emphasize population consequences as a function of demography (population rescue by spillover of excess individuals into poor quality habitat) (Pulliam 1988). In contrast, traps emphasize population consequences as a function of cue-response behavior (Patten & Kelly 2010). Sinks and traps are significant to conservation biology as being mechanisms for explaining (and then mitigating/ preventing/rectifying) population decline, extirpation, and extinction (Fletcher *et al.* 2012).

"This scenario of habitat modification lowering nest success and nest temperatures despite adaptive nesting behavior constitutes an ecological trap (Gates and Gysel 1978). An ecological trap exists when human modifications of the habitat in which populations evolved occur at a rate faster than the populations can respond, resulting in populations somewhat poorly adapted to cope with the altered habitat. . . . the decoupling of habitat attractiveness and suitability for nest success was the result of human caused landscape-level changes. . . . human modifications (i.e., houses and trees) have severed the connection between ground vegetation characteristics and nest temperatures observed at the NWR site." (Kolbe and Janzen 2002) For another example, though the environmental cues may appear favorable to a turtle, the habitat is actually severely degraded by increased depredation (Kristan 2003).

The Virginia site has sandy soils, is open to the sun, and lays closeby a stream, all characteristics perceived to be conducive to Turtle nesting use (Beuche *et al* 1997b). However, this site, a roadbed closed to public vehicular use, is used by pedestrians, equestrians, and bicyclists. Nests are trampled and soil is compressed. In addition, predators are of course drawn to the road as an access and foraging route. Seven nests were observed dug up and predated in a single day (Krichbaum 2009). In addition, Akre and Ernst (2006) observed 18 nests disinterred at another VA location, a utility corridor (as the road, another anthropogenic edge/ruderal habitat).

Habitat edges (habitat at the periphery of a patch) are often implicated in ecological traps (Battin 2004, Robertson & Hutto 2006). The edge effect typically of concern with ecological traps is that from predation. Landscape level changes have altered predator abundances and distributions, with consequent impacts on attributes such as nest success (Misenhelter & Rotenberry 2000, Weldon & Haddad 2005).

It is possible that female Wood Turtles can be enticed to use artificial nesting sites fabricated at safe areas instead of nesting at roadside or other trap habitat (Buhlmann & Osborn 2011). This would be an instance of increasing cues to a novel undervalued resource. The use of such artificial mounds can result in a high percentile of eggs hatching as well as healthy hatchlings (Paterson *et al*. 2013). Care must be taken that such fabricated nesting areas are not sited in such a way that they themselves then serve as ecological traps; *e.g.,* they must not be fabricated at edges or other habitats with high predation pressure (Weldon & Haddad 2005).

Improving or protecting the quality of the matrix or other habitats outside of protected areas can be crucial (Hansen & DeFries 2007, Quesnelle *et al*. 2013). At some locations it may be desirable and possible to alter matrix or edge habitat so it is avoided. Regarding the Gopher Tortoise (*Gopherus polyphemus*), McCoy and colleagues (2013) suggested that if grass height was substantially reduced by more intensive mowing or grazing at suitable times (early in the season), then this alteration/removal of the cue may lead to non-selection of this low quality habitat.

(3) The potential effects of climate change on the species and its habitat.

Within the Wood Turtle's range, across a multitude of spatio-temporal scales and biological levels humans are having profound impacts upon biodiversity. Drivers of these impacts include deforestation, agriculture, industrial development, urbanization, invasive species outbreaks, and climate change; all of which can be enfolded under the rubric "HIREC" (human induced rapid environmental change) (Robertson *et al*. 2013). Many taxa are under concurrent stress from multiple drivers (Harnik *et al*. 2012); this is the case for Wood Turtles. In general, HIREC may result in altered phenologies, community dynamics, abundances, and distributions (Urban *et al*. 2014, Lavergne *et al*. 2010). Population viability and abilities to shift ranges are constrained by habitat availability (Hodgson *et al*. 2011a). One of the mechanisms for such a HIREC constraint may be "ecological traps" (Patten & Kelly 2010).

Biota exhibit four basic responses to environmental change: plasticity (phenotypic), adaptation (genotypic), movement (behavioral), and extinction (disappearance). Except for the last, these can be considered as multiple modes of rescue (*i.e.*, avoidance of extinction). And, except for extinction, the responses are not mutually exclusive. One response can promote or retard the others (Chown *et al.* 2010). For example, plasticity is often viewed as a mechanism for buying time in the short term for adaptive evolution to progress in the longer term (Munday *et al.* 2013).

Constraints on adaptive evolution (Raup 1994, Hoffman & Sgro 2011) include low population size – the size of an affected population being crucial (Bell 2012), and limited genetic variation (Bell & Gonzalez 2009). Both of these constraints appear in Wood Turtles (see discussion and references in above "Population biology" section). Reduced evolutionary potential in small populations is due to the interplay of multiple factors, *e.g.*, stressful environmental conditions, reduced individual fitness, or reduced genetic variation (Willi *et al.* 2006).

There is evidence that some populations can evolve rapidly, apparently in as few as 25 generations (Bell 2013, Stuart *et al.* 2014). However, much of the evidence for this adaptive rapidity comes from taxa with large populations and high fecundity (Munday *et al.* 2013). With their genetic, life history, and demographic constraints, Wood Turtles and other chelonians may have little potential for such evolutionary rescue when confronted with rapid environmental change (Avise *et al.* 1992, Amato *et al.* 2008, Rödder 2013, Quintero & Wiens 2013, Vander Wal *et al.* 2013)

Population connectivity may be essential for maintaining regional viability of populations (Cushman 2006). Connectivity for dispersal/gene flow also contributes to the high standing genetic variability that may be necessary for potential adaptive evolution or tracking of suitable habitat. Connectivity is a patch-scale or a landscape-scale concept (Fischer & Lindenmayer 2007, Lindenmayer *et al.* 2008). Range expansion into new climate space depends upon both species and landscape characteristics. It is a function of intrinsic and extrinsic factors, *i.e.*, dispersal capability arising from characteristics of the specific organism (morphology, physiology, ecology, behavior) as well as attributes of the specific landscape (physical connectedness and resistance to movement) (Zeller *et al.* 2011). Due to their limited vagility, turtles in general, including Wood Turtles, are vulnerable to recovery or recolonization problems associated with habitat fragmentation (nevertheless, assumed degree of vagility may not be a good predictor of gene flow across a landscape (Davy 2013)).

Extant species of Nearctic turtles responded to past periods of GCC in the Pleistocene apparently by range tracking (Rödder *et al.* 2013). With conservative physiological tolerances (Stephens & Weins 2009, Rödder *et al.* 2013) and low potential for rapid adaptive evolution (Quintero & Weins 2013, Vander Wal *et al.* 2013), it can be expected that they will (attempt to) shift their ranges in the near future should climatic conditions continue to change. A major problem with range tracking in the future is that suitable climate-space may lie totally outside some taxa's current ranges. Using climate envelope species distribution models ("SDMs") for 199 chelonian species, Ihlow and colleagues (2012) concluded that future climate change may cause range contractions for 86% of species and projected climatic niches for 12% would be completely outside their current range. Moreover, even if an organism is capable of moving/dispersing, there may not actually be any suitable habitat in the new climate space, or it may be anthropogenically degraded or otherwise of low quality (Rödder 2010, Pike 2013).

Dispersal presupposes that there is something that can move, thus it is crucial to maintain sources of propagules (large populations/expansive habitats) (Hodgson *et al.* 2011b). Beyond all these constraints, in the face of massive anthropogenic domination and fragmentation of landscapes (Sanderson *et al.* 2002, Forman 2000, Riitters *et al.* 2002), the looming question for Wood Turtles and a multitude of other taxa is: How realistic are the probabilities for range shifts in response to climate change and other HIREC? Will taxa then be forced to adapt or perish? (Schiffers *et al.* 2012)

Wetland species, such as most turtles (Bour 2008), encounter an additional problem from moving higher in elevation or north in response to temperature change: the organism may move up or north, but the wetland stays put. Or the wetland disappears, precluding rescue through *in situ* plastic or evolutionary responses.

The results of both Rödder *et al.* (2013) and Ihlow *et al.* (2012) suggest the previous presence of and future necessity for climatic microrefugia resulting from heterogeneous topography (Dobrowski 2010, Rull 2010). Forecasting and hindcasting SDMs and habitat suitability models can be used to identify potential thermal/hydric microrefugia, as well as stepping stones and corridors to link source and destination habitats (Vos *et al.* 2010, Hagerty *et al.* 2011, Hodgson *et al.* 2011).

Though active at a wide range of body and ambient temperatures, Wood Turtles are active at lower environmental temperatures than most other emydid species (Ernst 1986). Their normal activity range was 7.5–30.0 °C, and activity was noted at temperatures as low as 3 °C (*id.*). Unlike the great majority of other reptiles, they may be observed as active when air temperatures are only in the 50s F. or even less. Thus, Wood Turtles are at risk from the warming and drying associated with contemporary climate change. Climate change could change Turtle habitat conditions, diminishing their quality and making them warmer and drier. Even if the Turtles could proceed northward at a rate commensurate with the warming/alteration of their current habitat, it would be difficult to impossible to do so at present due to the vast fragmentation, degradation, and disruption of their habitat resulting from human development.

To facilitate range shifts, conservationists need to think on larger spatial and temporal scales in order to link present and future climate zones (Vos *et al.* 2008, Vos *et al.* 2010). This involves the strategic placement of corridors and/or steppingstones so as to provide potential colonization routes and eliminate geographic bottlenecks. Relatively small amounts of such additional habitat can significantly facilitate the speed and probability of range shifts/expansion (Hodgson *et al.* 2011). The speed of with which expansion can occur is of critical import for viable responses to climate change. Thus, spatial responses by species to climate change require facilitating range shifts and compensating for additional population fluctuations.

Vos *et al*. (2010) outline the necessary steps for achieving these adaptive landscapes or "**climate adaption zones**":

1) Increase the carrying capacity of protected areas by either enlarging the size of protected areas (*e.g.*, this will incorporate more heterogeneity) or by improving habitat quality;

2) Increase spatial heterogeneity by accommodating natural landscape processes (disturbances, gradients) – important as a means for avoiding synchronized disturbance in all patches (which can lead to metapopulation instability and extirpation/extinction);

3) Identify bottlenecks so as to improve connectivity - when the distance between suitable habitat patches exceeds the dispersal capacity of a species, or a species-specific dispersal barrier occurs in the landscape, add new habitat (corridors or steppingstones) between existing patches or increase matrix quality.

Though Hodgson *et al*. (2011) and others recognize that dispersal ability and inter-patch distances are clearly critical factors, there is more to consider. If the corridors or steppingstones are small or narrow, they could be overrun with edge effects (such as increased predation). Such habitats could then actually impede dispersal instead of facilitating it. In this way ecological traps could slow or prevent range shifts in response to GCC or HIREC. So habitat restoration/reservation could actually increase extinction probability if ecological traps are not properly considered (Severns *et al*. 2011, Robertson *et al*. 2013). The viability of populations within protected reserves may be dependent upon populations and ecological processes that exist or begin outside of the protected area (Harris *et al*. 1996, Hansen & DeFries 2007). Both within and outside protected areas, the potential for the existence or fabrication of disruptive ecological traps must be recognized and addressed.

If Wood Turtles are forced to move into higher altitudes in response to warming climate they will rapidly run out of habitat. The upper altitudes are generally drier and may become more so with altered climatic regimes. Many of the upper elevation streams within the Turtle's range are rockier higher gradient streams with swifter currents, lower overall nutrients, reduced summer flow, and without deeper pools or generous LWD loadings (Krichbaum pers. obs.). Turtles overwintering in such steeper places also run the risk of being killed, maimed, or swept away by winter and early spring floods (Jones 2009). Further, in Massachusets, for example, the number of floods and flash flood events is increasing (*id*.).

The riparian areas at higher altitudes are generally more narrow and the associated forest may be without the diversity of habitat conditions, structure and composition found at the lower sites. Due to edaphic and geological conditions many streams, particularly at higher elevations, can be relatively low fertility and acidic sites simply not conducive to supporting a complexity of aquatic habitat and populations or associated ground-floor diversity in the surrounding forest. In short, mountainous elevations generally do not provide the high quality habitat that the Turtles prefer or that are capable of sustaining healthy population numbers (Jones 2009; Krichbaum pers. obs. – *ca*. 1000 days hiking/camping in the Appalachians).

Cooling, particularly at more northern locations within the Wood Turtle's range such as New England, may also be problematic. Aside from potentially deleterious (and cascading) effects on the fauna and flora of the communities occupied by the Turtles, other more direct impacts may ensue.

Reductions in climatic temperatures or greater frequencies of cold weather may lead to even more nest failures, with subsequent impacts to recruitment and population viability. Incubation time is most dependent upon temperature (Harding 1991, Walde 1998); in the northern portions of the species range at least 50% of nests may not hatch in any given year (Compton 1999). Hatching success of eggs may be low or virtually nil in cool years (Foscarini 1994, Smith 2002).

Clearly, much work remains to be done to identify and implement these future conservation necessities for ensuring long-term sustainability of Wood Turtle populations. To ensure the continued existence of source populations/habitats (propagules) for the future, Wood Turtles and their habitats need to be accorded the strongest possible protection now; *e.g.*, increasing population carrying capacity by enlarging/improving the size/quality/protection of protected areas (Wood Turtle "core habitat").

Sec. 4 Considerations

(1) What may constitute "physical or biological features essential to the conservation of the species," within the geographical range occupied by the species;

For habitat to be occupied it must supply the basic requirements of hibernacula, mating opportunities, nesting sites, food, cover, thermoregulation, and hydration. Use of "range" maps can significantly overestimate the actual occurrences and distribution of a species (Jetz *et al*. 2008). Range maps are misleading as to the actual extent of the Wood Turtle's distribution. Although the Turtle is wide-spread in "range", it actually has a restricted distribution (see macro-scale habitat constraints, such as elevation and stream gradient, in Jones & Willey 2015).

Occurrence of actual populations is recognized to be localized and spotty (see, *e.g*., Bowen and Gillingham 2004). In other words, the actual "area of occupancy" is only a tiny fraction of the "extent of occurrence" based on range maps. For example, the Turtle's occupied area was calculated to be only *ca*. 0.3% of the extent of its range in Canada (COSEWIC 2007). In addition to actual occupancy, overall "range" maps can also misrepresent the species47' recovery potential as well. Such a "method overestimates recovery potential for most species because they are often restricted to particular habitats that may only extend across a small proportion of the actual natural habitat within the total range map for the species." (Kerr and Deguise 2004)

Forested areas associated with low gradient clear flowing waters with hard substrates (*e.g.*, sand, gravel, cobble, boulders) appear to be preferred (Jones and Willey 2015).

The extent of upland terrestrial habitats used by Wood Turtles far exceeds the size of traditionally protected buffer zones along waterways. Protecting "riparian areas" or "wetlands" is not sufficient. Various state and federal regulations are in place to ostensibly 'protect' riparian areas, but I do not know of any that are sufficient to protect Wood Turtle populations and their habitat. The legally required protected zones associated with waterways are invariably narrow.

For example, the full riparian areas of permanent and intermittent streams are not necessarily protected from logging on the GWNF. Under the current Forest Plan, only the first 100 feet of the riparian areas around perennial streams are considered "unsuitable for timber management" (though logging can still occur); the Plan provides for a "riparian corridor" of only 50 feet around intermittent streams (GWNF Revised LRMP 4 – 119-126). Ephemeral streams receive no direct explicit protection in the GWNF Plan. And old stream channel braids that are presently dry are also open to cutting. Intentional burning can occur right up to the streamside.

The "Best Management Practices" in place in Virginia and elsewhere with regard to waterways are likewise inadequate for protecting Wood Turtles. For instance, the GWNF Plan "meets or exceeds State Best Management Practices." (2014 LRMP A – 3).

Stream buffers are generally applied so as to protect some aspect of water quality (Wenger 1999, Phillips *et al.* 2000). It is crucial to recognize and address the fact, however, that riparian zones are not just buffers for aquatic habitat, but are themselves core habitat for various taxa (Reese and Welsh 1997). Hence, the riparian zones/areas themselves need to be buffered from, for example, edge affects or recreation or roads. And beyond this, as detailed in above in (1)(a), Wood Turtles range far outside of "riparian areas" and use habitats that are not riparian or wetlands (Krichbaum unpub. data). Therefore, for this species we must expand our consideration and our protective measures beyond "riparian areas" or "wetlands". See Burke and Gibbons 1995, Semlitsch and Jensen 2001, Semlitsch and Bodie 2003, Crawford and Semlitsch 2007, Congdon *et al.* 2011, Quesnelle *et al.* 2013.

The lack of adequate no-harvest buffers along all classes of stream channels means the recruitment of LWD will be reduced, thus impeding the provision of this critical habitat element in streams. A similar impoverishment of course may occur in terrestrial habitat when the Turtle's core habitat is subjected to intensive timber harvest. The intensive and extensive logging that took place in recent historical times in the East, as well as that which is ongoing, removed a great deal of the material (*viz*., large old trees) that would have become large woody debris (LWD) (Dolloff 1996). Consequently there has been a long-term impoverishment of this material, in both aquatic and terrestrial habitats. For instance, 50% of the 392 miles of streams surveyed in the George Washington National Forest from 1995 to 2005 did not meet desired levels of large woody debris deemed necessary for healthy stream systems (USFS GWNF DCER 2007). In a recent year of stream surveys, taken solely in the GWNF's North River RD, 78% of all streams were deficient in large woody debris. As regards this impoverishment, the past is prologue.

A proper management strategy for Wood Turtles will provide stringent protection for waterways as well as adjacent lands.

Overwintering sites and aquatic habitat

Implementation of logging clearly removes sources of LWD and further reduces future inputs of this material (already reduced due to past logging and burning in areas) by removing the boles that would eventually provide the longest-lasting and largest of such material. LWD provides Wood Turtles with escape cover, hibernacula, thermo-/osmo-regulation sites, and foraging opportunities.

Large woody debris plays an important role in structuring stream habitats (Welsh *et al*. 1998). Woody debris, particularly large logs, are particularly important for pool formation, with pool density higher in old-growth reaches (Keeton *et al*. 2004). For example, at Wood Turtle stream sites in the mountains of VA and WV, many stream pools, particularly those deep enough to serve as hibernacula, are either directly formed or significantly influenced by LWD (Krichbaum pers. obs.). The pools formed by debris dams are small-scale nutrient catchment basins that strongly influence community structure (*i.e*., the provision of potential Wood Turtle prey organisms) (Pringle *et al*. 1988). When woody debris is removed from a headwater system, a decrease in macroinvertebrate abundance and biomass has been noted (Wallace *et al* 1999, Ogren and King 2008).

Because of the past and ongoing intensive logging and other human-caused disturbance that has taken place, there is actually an impoverishment of dead wood ("large woody debris" or what are sometimes referred to as "fuels") on the great majority of forest sites in the East (Dolloff 1996 and USFS GWNF 2007). It takes a long time to recover significant loadings of large material (Webster *et al*. 2008), perhaps centuries (Hornbeck and Kochenderfer 2000). Streams draining late-succesional and old-growth riparian forests display a gradual, but significant increase in LWD loadings (Hedman *et al*. 1996, Keeton *et al*. 2007). In most places the aging and recovering eastern forests are only now reaching the state where significant LWD loadings are occurring.

(2) Where these features are currently found;

The features discussed above in (1), and in (1)(a,c) and (2)(a), are found on public and private lands at various sites within the Turtle's range. Individual states keep occurrence records of the species; also see Jones & Willey 2015 for listings of watersheds and ecoregions with known occurrences (Iowa, Michigan, Wisconsin, and Minnesota are not included).

(3) Whether any of these features may require special management considerations or protection;

For Wood Turtles the terrestrial zones that generally extend out to *ca*. 300 meters from waterways certainly can be considered "**core habitat**" (*sensu* Semlitsch and Jensen 2001, and Semlitsch and Bodie 2003, Congdon *et al*. 2011) where conservation efforts for this species can be focused (see discussion and references at (1)(a)) (this is not to say that other portions of their habitat can not also be considered as core habitat). For instance, Vermont recognizes that "the wood turtle uses streams and rivers for overwintering, and uses adjacent riparian areas up to 300 meters from the water's edge for foraging, breeding, nesting, and dispersal." (Vermont 4 – 68) And New Jersey uses a 322-meter stream buffer to identify Wood Turtle habitat (NJ Landscape Project at http://www.njfishandwildlife.com/ensp/landscape/index.htm).

One of the reasons expansive (relative to current stream buffers) protected zones are needed for the Turtles is not only to address the direct protection of their "core habitat", but also to mitigate, diminish, or prevent "edge effects" that may also reduce habitat quality. Timber cuts, roads, development, and other conversion of habitat result in the fabrication of ecological edges with a multitude of deleterious impacts. Edge width or depth/distance of edge influence (DEI) is the result of the penetration distance of various environmental variables and gradients (*e.g.*, soil temperature, air temperature, litter moisture, photosynthetic active radiation effect on vegetation patterns, alien plant species invasion, and ingress by herbivores or predators) (Zheng and Chen 2000).

The impact of depredation upon Wood Turtles cannot be overemphasized. It is believed that many of the smaller predator species have experienced great population increases due to direct and indirect human subsidy (see Mitchell and Klemens 2000). Predation pressure is having devastating impacts upon nesting success and subsequent recruitment throughout the Wood Turtle's range at various site conditions (see, *e.g.*, Siart 1999, Brooks *et al*. 1992, Hunter *et al*., 1999, Harding 2002, Paradis *et al*. 2004, Bowen & Gillingham 2004, Jones and Willey 2015).

(4) Specific areas outside the geographical area occupied by the species that are "essential for the conservation of the species"

[blank]

(5) What, if any, critical habitat you think we should propose for designation if the species is proposed for listing, and why such habitat meets the requirements

of section 4 of the Act.

The ESA mandates that, when the USFWS lists a species as endangered or threatened, the agency generally must also concurrently designate critical habitat for that species. Section 4(a)(3)(A)(i) of the ESA states that, "to the maximum extent prudent and determinable," the USFWS:

> shall, concurrently with making a determination . . . that a species is an endangered species or threatened species, designate any habitat of such species which is then considered to be critical habitat . . . .

16 U.S.C. § 1533(a)(3)(A)(i); see also *id*. at § 1533(b)(6)(C).

The ESA defines the term "critical habitat" to mean:

> (i) the specific areas within the geographical area occupied by the species, at the time it is listed in accordance with the provisions of section 1533 of this title, on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and
>
> (ii) specific areas outside the geographical area occupied by the species at the time it is listed in accordance with the provisions of section 1533 of this title, upon a determination by the Secretary that such areas are essential for the conservation of the species.

16 U.S.C. §1532(5)(A).

Therefore, critical habitat should ensure an adequate amount of protected habitat in a spatial configuration that allows for the long-term survival and recovery of the species, including a network of interconnected reserves that provide for self-sustaining populations, genetic interchange, migration and dispersal. These are basic tenets of conservation biology, as well as ecosystem management (Primack 2010, Groom *et al*. 2006, Grumbine 1994). The designation and protection of critical habitat "provide[s] a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved." 16 U.S.C. §1536(a)(2).

The Ninth Circuit's decision reiterated that *recovery* is a key purpose of the Endangered Species Act, one that is largely implemented through the critical habitat provisions of the Act. The court noted that the Service had been operating under regulations that failed to acknowledge the crucial and distinct role of critical habitat: "That the agency was operating under a regulation that we now hold was impermissible has an inescapable bearing on the requisite showing of whether the [Service] considered recovery in its critical habitat inquiry." *Gifford Pinchot Task Force v. U.S. Fish and Wildlife Serv*., 378 F.3d 1059, 1069-1071 (9th Cir. 2004).

The biological needs of the Wood Turtle are sufficiently well known to permit identification of areas as critical habitat.

The information contained in the petition, this comment, and the references cited indicate that when designating critical habitat for this species the USFWS must give special consideration to:

the areas extending out at least 300 meters from both banks of occupied stream reaches.

This is a prudent minimum, as it says nothing about the habitat connecting populations, neither does it directly address unoccupied habitat that may be necessary for recovery of the species, nor does it directly address female movements to nesting sites that may lie outside of this stream-centered core habitat. Nesting may entail long-distance travel by females to reach a particular site; for example, 3 kilometers (Paradis *et al*. 2004, Krichbaum pers. obs.). To protect the ecological integrity of the above limited zone of critical habitat, as well as provide protection for movements to nesting areas will require more expansive protection zones (see Congdon *et al*. 2011 with regard to Blanding's Turtles (*Emydoidea blandingii*)).

In general, accommodate natural disturbance processes in these areas of core/critical habitat (that does not mean letting conflagrations burn them to the ground). Habitat enhancement should generally focus on the restoration of natural structural and hydrological features (see, *e.g*., Keeton 2006).

At deciduous, mixed, and pine forested sites in VA and WV the mean basal areas at plots where Wood Turtles were located were 23.66m^2/ha (194 plots in VA) and 24.19m^2/ha (122 plots in WV) (Krichbaum unpub. data). Hence, in places with high density of trees (see "Large" and "Medium" numbers at Table 2 and Fig. 6), it is possible that fabrication of small canopy gaps by downing some trees (individual tree or small (<0.2 acre) group selection cuts) may improve habitat for Wood Turtles: for example, cutting of *ca*. 10 or fewer canopy trees/acre (generally those > 25cm dbh), 20 or fewer midstory trees/acre (generally those 10-25cm dbh). Any cutting should be done in the winter when Wood Turtles are aquatic. Retention of downed trees on site would be best for Wood Turtles and other wildlife (non-commercial cut and leave). If trees are to be removed, low impact methods such as horse logging would be employed.

In addition, where possible, roads should be closed to vehicular traffic in Wood Turtle core habitat. Habitat restoration may involve road obliteration and revegetation. It may be best, however, to maintain some sections of unpaved roads and their embankments as nesting sites, dependent upon suitable aspect, slope, and substrate.

Thank you for your consideration.

Sincerely,

ATTACHMENTS – also see papers on separately submitted by mail flash drive

1. Study Site – referred to in comments

This project takes place at two sites close to the species southern range limit on the George Washington National Forest ("GWNF") of Virginia (Stream A) and West Virginia (Stream B) in the vicinity of 39°N and 78°W. Both sites are part of the Ridge and Valley Subsection (M221Aa), Northern Ridge and Valley Section (M221A) of the Central Appalachian Broadleaf Forest – Coniferous Forest – Meadow Province (M221) (McNab *et al*. 2007). Forests here are within the Oak – Chestnut Region of Braun (1950) and the Appalachian Oak Section of the Mesophytic Region identified by Dyer (2006). Both sites are in the Potomac River drainage basin of the Chesapeake Bay watershed. Average annual precipitation measures *ca.* 96 cm, of which *ca*. 27cm falls in June through August (NCDC 2013). Elevations in the proximity of the turtle occurrence points range from *ca*. 250-600m asl, although surrounding ridges within the watersheds reach *ca*. 850m asl.

The two sites are located in mountainous terrain with numerous drainages (mostly ephemeral and intermittent) feeding small main streams. On the National Forest, Stream A (in VA) is *ca*. 14km in length, while Stream B (in WV) is *ca*. 3km in length. The two groups of Wood Turtles are on opposite sides of a mountain ridge / drainage-divide with the turtle points in closest proximity at the two sites being *ca*. 3km apart. Both streams are low gradient 1st – 3rd order streams with mostly pebble-cobble-boulder substrates and riffle-run-pool habitats. Summer water depths at both streams range from 3-80 cm, with channel widths of 1-5 m. Associated with Stream A are broad gently sloping (1-7° inclination) riparian flats and and upland benches. In contrast, Stream B is more sharply incised, with steeper slopes closeby the stream and generally narrower riparian flats.

Common overstory canopy tree taxa include *Quercus (alba, cocinna, prinus, rubra,* and *velutina), Acer rubrum* and *saccharum, Fraxinus americana, Betula lenta, Liriodendron tulipifera*, *Nyssa sylvatica, Carya* spp., and *Pinus* (*rigida, strobus,* and *virginiana*). Common midstory subcanopy tree taxa include smaller individuals of the above species as well as *Ostrya virginiana, Amelanchier* spp.*, Cornus florida*, and *Hamamelis virginiana*. Common shrub and woody understory species include *Rhododendron* spp. (azaleas), *Ilex verticilata, Viburnum* spp., *Lindera benzoin, Vaccinium* spp., *Gaylusuchia* spp., *Rubus* spp., *Smilax* spp., *Lyonia* spp., *Kalmia latifolia*, and *Parthenocissus quinquefolia*. Herbaceous ground floor species include *Viola* spp., *Potentilla* spp., *Mitchella repens, Gaultheria procumbens, Epigaea repens, Goodyera pubescens, Desmodium* spp., *Medeola virginiana, Dioscorea villosa, Smilacena recemosa, Chimaphila maculata, Hieracium venosum, Oxalis stricta, Uvularia* spp.*, Lycopus* spp., *Gallium* spp., *Scutellaria* spp., *Amphicarpaea bracteata, Prenanthes* spp., *Lobelia* spp. *Thalictrum* spp., *Pedicularis canadensis, Impatiens capensis, Aster* spp., *Solidago* spp., *Eupatorium* spp., *Boehmeria cylindrica*, *Panicum* spp., and *Carex* spp.

Though many herbaceous and woody species are held in common, the forests found at the two sites are noticeably different. Stands at Stream A are predominantly oak forest types: FT3 = White Pine, 10 = White Pine/Upland Hardwoods, 52 = Chestnut Oak, 53 = White Oak – Northern Red Oak – Hickory, 54 = White Oak, 56 = Tulip Poplar, 59 = Scarlet Oak, 60 = Chestnut Oak – Scarlet Oak (numerical forest typing as per USFS). In contrast, stands at Stream B are comprised of a greater proportion of relatively more-xeric pine and mixed-pine forest types: FT10 = White Pine/Upland Hardwoods, 33 = Virginia Pine, 42 = Upland Hardwoods/White Pine, 45 = Chestnut

Oak – Scarlet Oak – Yellow Pine, 52 = Chestnut Oak, 53 = White Oak – Northern Red Oak – Hickory.

The forest at the WV study site is relatively undisturbed, with forest stands >100 years of age predominant. One old unpaved logging road enters the site. The most recent logging on the National Forest here took place perhaps *ca*. fifty years ago; logging on a patch of adjacent private lands occurred within the last ten years. Agricultural uses occur on some nearby privately owned lands (with the closest perhaps 400 meters from the study site).

Although, compared to many other Wood Turtle sites, the VA study site is relatively undeveloped and mostly forested, it is not pristine. A gravel road, open to the public at various times of year, runs the length of the site. A maintained electric line corridor bisects the area. A trail used by equestrians, bicyclists, and pedestrian hikers also runs closeby the Run for several miles. Commercial timber sales have occurred here in the recent past; most recently, even-age logging of 50 hectares of mature forest, all within 30-300 meters of Paddy Run, occurred *ca.* 2008. Even-age logging also took place from 20-60 years ago.

2. MARK population analysis

Data Analysis Procedures: Observations of individual Turtles were combined and tallied by year. As no juveniles were recaptured, only data pertaining to adults were used in the analysis (see, *e.g.*, Daigle and Jutras 2005). The adult turtle capture-recapture data were split into two groups, males and females. The sex ratio of adults was compared to a 50:50 sex ratio with a Chi-square goodness-of-fit test. I used the program MARK vers. 7.1 to model/estimate survival and recapture parameters, population size, and the geometric rate of population growth (λ).

Using the nine-year mark–recapture data, I analyzed adult capture histories by year. I used a hierarchical model testing approach to examine sex-specific apparent survival (signified by ϕ) and capture probability (signified by ρ) of marked adult animals in open population Cormack-Jolly-Seber models (allowing births/deaths and immigration/emigration). The parameter ϕ_t is the probability that an individual alive at time *t* will also be alive and in the population at time *t+1*. Emigration off the study site results in apparent survival being "true survival" times the probability that the animal remains on site (fidelity probability). Apparent capture (or encounter) probability is the product of the probability an individual is available for encounter (has not temporarily emigrated) and the true probability of detection (Cooch and White 2013). The *t* throughout this analysis refers to years, so ϕ is an annual probability of survival and ρ is an annual probability of capture. The size of the study area was constant and equal catchability of marked and unmarked animals was assumed (and validated by RELEASE Test 2).

I began by using the model with annually variable survival and capture probabilities that also differed for each sex (ϕ(sex(t))ρ(sex(t))) as the least restrictive model, *i.e.*, a totally time-dependent saturated model that estimated values for 26 parameters. Other models were examined that included fixed (*i.e.*, constant or non-time-dependent, signified by a ".") capture probability (ρ(.)), or fixed survival probability (ϕ(.)), or both fixed capture and survival probabilities (ϕ(.)ρ(.)). I also examined mixed models, with one parameter constant and the other time-dependent, including variation between sexes (denoted by "sex" in parentheses). In some models the parameterization for survival, capture, or both were equal between the sexes (*e.g.*, equal constant survival for both sexes). The best-fit model was determined by comparing AIC_c values for each model, the model with the lowest AIC_c value being ranked as best. I considered models with AIC_c or $QAIC_c$ scores within three of the top score to be well supported.

Results from the above analysis were then used to estimate population size by running similar models in the POPAN routine in MARK. Model parameters included capture probability (ρ), apparent survival (ϕ), and probability of entrance ("pent") into the population. Constant or time-dependent survival and capture parameters were used, with and without sex differentiation. In all models "pent" was variable with time.

I used Pradel survival and lambda models in MARK to estimate seniority (γ) and realized population growth rate (λ). Pradel models assume that an animal can enter the study on any occasion (Cooch and White 2013). Seniority is a form of hindcasting in which transitions among capture occasions are examined backwards in time; Pradel estimations of gamma are equivalent to analyzing reverse capture histories with CJS models (Mitro 2003). The parameter γ_t is the probability that an individual alive at time *t* also was alive and in the population at time *t-1*. In Pradel models, realized λ is the growth rate only of the age class represented in the encounter history database, in this case adults exclusively. Therefore, this realized lambda may not be equal to the growth rate of the total population. Realized λ is equal to the ratio of abundances in successive time steps; however, it is also equal to the ratio of apparent survival and seniority, as well as the sum of apparent survival and recruitment (*f*):

$$\lambda = \frac{N_{t+1}}{N_t} = \frac{\emptyset_t}{\gamma_{t+1}} = \emptyset_t + f_t$$

The Pradel models were parameterized with various combinations of constant or time dependent or sex specific survival, capture probability, and gamma.

The MARK module RELEASE was used to examine model goodness-of-fit, dispersion, and variance inflation factors ($\hat{c}$ or c-hat) used for adjusting the likelihood term, yielding the quasi-likelihood adjusted QAIC*c*. Test 2C addresses capture heterogeneity; it tests the CJS assumption that all marked animals should be equally 'detectable' at occasion *i+1* independent of whether or not they were captured at occasion *i*. For valid estimates of abundance in open populations, both marked and unmarked animals must have the same probability of capture (Cooch and White 2013). Test 3 deals with differential survival; it tests the assumption that all marked animals alive at time *i* have the same probability of surviving to *i+1*.