

Conservation Plan for the Bog Turtle

(*Glyptemys muhlenbergii*)

in North Carolina



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NC Wildlife Resources Commission

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Version 4.1

TABLE OF CONTENTS

EXECUTIVE SUMMARY	1
BIOLOGICAL INFORMATION.....	3
Description and Taxonomic Classification	3
Life History and Habitat.....	3
Distribution and Population Status	4
THREAT ASSESSMENT	6
Reason for Listing.....	6
Present and Anticipated Threats.....	6
Summary of Threats	15
Historic and Ongoing Conservation Efforts	16
CONSERVATION GOALS	17
Goals.....	17
CONSERVATION ACTIONS.....	18
Goal A: Identify Threats to Bog Turtle Populations.....	18
Goal B: Maintain and Maximize the Number of Viable Populations	18
Goal C: Further Our Knowledge about Bog Turtles	26
Goal D: Expand Outreach Efforts.....	29
SUMMARY OF ACTIONS NEEDED	30
ECONOMIC IMPACTS	34
Potentially Affected Parties.....	34
Costs to NCWRC.....	35
Costs to Others.....	37
Efforts to Minimize Costs and Adverse Economic Impacts	38
Economic Benefits	38
GLOSSARY.....	39
LITERATURE CITED	41

1 **EXECUTIVE SUMMARY**

2 **Current Species Status**

3 The bog turtle [(*Glyptemys muhlenbergii*) southern population] is listed as Federally
4 Threatened due to Similarity of Appearance (T(S/A)) to the northern population (listed as
5 Threatened by USFWS). It is state listed as Threatened in North Carolina. The northern
6 population was listed because of threats to the turtles' habitat including degradation,
7 fragmentation, succession due to invasive exotics, and threats to the turtles including illegal
8 trade and collecting. The southern population was not simultaneously listed because
9 limited information existed at that time regarding threats and survey coverage. It has
10 become evident in recent years that the species faces many of the same threats in the
11 southern U.S. An estimated 80-90% of bogs have been lost in North Carolina because of
12 decades of land-use conversion. Bog turtle range in North Carolina is the Blue Ridge
13 Mountains and upper Piedmont eco-regions, with records existing in eight river basins. Bog
14 turtles have been documented in 24 counties, though some of those records are historical
15 only. In the past 10 years (2007-2016), only 18 sites have had 10 or more turtles captured.
16 Relatively few bog turtle populations remain, and most of those appear to be in decline.
17 There is significant concern for this species in North Carolina. Major threats to bog turtles
18 include vegetative succession, vehicles, habitat loss and degradation, predation,
19 development and changes in the watershed, and barriers to movement.

21 **Habitat Requirements and Limiting Factors**

22 Bog turtles are typically found in spring-fed bogs and fens with soft, saturated soils and
23 little to no canopy cover. Ideally, bog turtle habitat has deep, loose low-strength soil with
24 sphagnum mosses or similar low vegetation, unaltered or minimally altered hydrology,
25 subsurface root structures and/or tunnels, and minimal threats in the immediate area. The
26 wetlands that bog turtles inhabit in North Carolina are considered among the rarest and
27 most imperiled habitat types in the Southeast. A large proportion of known bog turtle
28 wetlands in North Carolina are still privately owned with no long-term protective
29 measures in place. About 60% of the wetland sites with at least one bog turtle captured in
30 the last 20 years (44 of 74 sites) do not have any protection. Relatively few bog turtle
31 populations remain, and most of those appear to be in decline.

33 **Conservation Goals**

34 Fortunately, bog turtle conservation in North Carolina is a collaborative effort among
35 partners. The overarching conservation vision for *Glyptemys muhlenbergii* is to protect and
36 restore the populations and habitats of this species to prevent extirpation and ensure long-
37 term viability across its current range in North Carolina for the next 100 years. Goals that
38 contribute to the vision are:

- 39 A. Identify threats to bog turtle populations
- 40 B. Maintain and maximize the number of viable populations
- 41 C. Further our knowledge about bog turtles
- 42 D. Expand outreach efforts

43 **Actions Needed**

- 44 1. Assess and address threats specific to high priority sites.
- 45 2. Protect habitat, with a focus on high priority sites, metapopulations, and sites with
- 46 landowners willing to sell.
- 47 3. Create a schedule of habitat management needs for all extant bog turtle populations.
- 48 4. Write management plans for bog turtle sites, prioritizing sites with complex and
- 49 immediate management needs, a population that would benefit, and that we have
- 50 permission to manage.
- 51 5. Conduct habitat management and restoration at high priority sites and
- 52 metapopulations.
- 53 6. Develop a decision framework for determining when population manipulation
- 54 techniques are appropriate and establish related policies and protocols.
- 55 7. Formulate a multi-faceted plan to fill in data gaps on bog turtle distribution.
- 56 8. Through planning, develop and implement a structured and scheduled population
- 57 monitoring plan.
- 58 9. Conduct research to answer critical questions about bog turtles and their ecology.
- 59 10. Develop and implement a robust education and outreach program and improve
- 60 communication and collaboration with key partners.

61

62

63

64 **BIOLOGICAL INFORMATION**

65 **Description and Taxonomic Classification**

66 The bog turtle (*Glyptemys muhlenbergii* Schoepff) is the smallest freshwater turtle in North
67 America. Its most distinguishing feature is a large, bright yellow to orange blotch on each
68 side of its brown head. The carapace and plastron are light brown to dark brown or black,
69 and the scutes on the carapace sometimes have a light center or pattern of lines radiating
70 out. It has a moderately domed carapace with a low keel, and the plastron is hinge-less. The
71 maximum straight-line carapace length is 11.5 cm (4.5 in) for males and 9.63 cm (3.8 in)
72 for females (Ernst and Lovich 2009).

73
74 The *Glyptemys* genus is comprised of only two species, the bog turtle and the wood turtle
75 (*Glyptemys insculpta*). Prior to 2001, the bog turtle and wood turtle were considered part of
76 the genus *Clemmys*, but morphological and genetic analyses indicated these two species
77 were much more closely related to each other than to spotted turtle (*Clemmys guttata*) or
78 western pond turtles (*Actinemys marmorata*; Holman and Fritz 2001). Thus, the bog turtle
79 and wood turtle were moved to the newly created *Glyptemys* genus, leaving the spotted
80 turtle as the sole member of the *Clemmys* genus.

81
82 **Life History and Habitat**
83 Female bog turtles are sexually mature at about 6-7 years, though this can vary
84 geographically (Ernst and Lovich 2009). They typically mate in spring, from March-June,
85 and 21-31 days after copulation, females lay their eggs, with most nests laid from May-July.
86 They choose locations in sedge and rush tussocks or sphagnum moss and lay between 1-6
87 eggs, with 3.1 on average reported from a Maryland study (Wilson et al. 2003).

88
89 The species is found in a variety of spring-fed bogs and fens that have soft saturated soils,
90 including the Swamp-Forest Bog Complex, Southern Appalachian Bog, French Broad Valley
91 Bog, Low Mountain Seepage Bog, and Southern Appalachian Fen (Schafale 2012). Habitat
92 typically is dominated by sedges and sphagnum moss, has thick soft muck, saturated soils,
93 and numerous springs, with some areas lacking canopy and others having shrubs and
94 scattered small trees (Buhlmann et al. 2008, Feaga et al. 2012). Plants often associated with
95 these wetlands include sedges (*Carex* spp.), rushes (*Scirpus* sp., *Juncus* sp.), sphagnum moss
96 (*Sphagnum* spp.), skunk cabbage (*Symplocarpus foetidus*), poison sumac (*Rhus vernix*),
97 alder (*Alnus* spp.), willows (*Salix* spp.), and a variety of ferns (Herman and George 1986,
98 Tryon 1990).

99
100 Most publications describe the habitat features observed in sites inhabited by bog turtles
101 rather than specifying the actual habitat needs of bog turtles. Moreover, many authors
102 refer to "suitable habitat" and "high-quality habitat" without clearly defining the terms.
103 Herein we define these terms as used in this document based on what we know of bog
104 turtle ecology and habitat use in North Carolina (see Glossary). These terms as defined
105 here are likely applicable to bog turtle habitat in other states and regions. *Suitable* habitat
106 will contain the following at a minimum: 1) soft, saturated soils, 2) spring-fed hydrology,
107 and 3) an area with low vegetation (no canopy) that gets full sun. *High-quality* bog turtle
108 habitat consists of the above plus the following characteristics: 1) areas with deep, loose

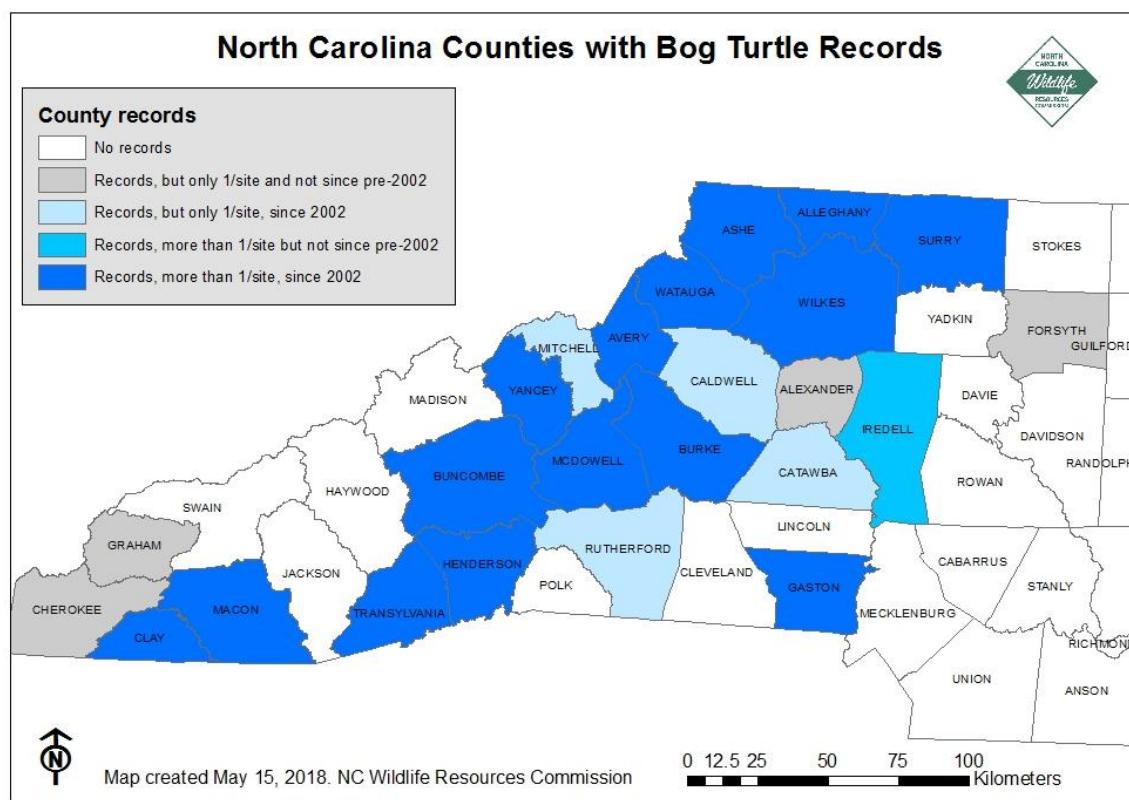
109 low strength soils (Feaga et al. 2013), 2) presence of sphagnum mosses, rushes, sedges, and
110 some wetland shrub species, 3) mosaic of low and shrubby vegetation with 1 or more
111 relatively large areas with very low vegetation (ideally sphagnum, but also rushes and
112 sedges) that receive full sun, 4) relatively unaltered hydrology with stable ground-water
113 levels that are $8\text{ cm} \pm 1\text{ cm}$ ($3.1\text{ in} \pm 0.4\text{ in}$) average depth from surface over multiple years,
114 without flooding and inundation (Feaga 2010), 5) presence of subsurface root structures
115 and/or tunnels, 6) adequate vegetation to conceal turtles when basking on surface, 7)
116 minimal threats within habitat and/or adjacent to property (e.g., busy roads, over-
117 abundance of predators).

118

119 Distribution and Population Status

120 In North Carolina, the bog turtle is found in the Blue Ridge Mountains and upper Piedmont
121 eco-regions, and records exist within the Middle Tennessee-Hiwassee, Upper Tennessee,
122 French Broad-Holston, Savannah, Santee, Upper Pee Dee, Kanawha, and Roanoke river
123 basins (Beane et al. 2010; NCNHP 2017). The species has ¹been documented in the
124 following 24 counties: Alexander^{1,2}, Alleghany, Ashe, Avery, Buncombe, Burke, Caldwell²,
125 Catawba², Cherokee^{1,2}, Clay, Forsyth^{1,2}, Gaston, Graham^{1,2}, Henderson, Iredell¹, Macon,
126 McDowell, Mitchell², Rutherford², Surry¹, Transylvania, Watauga, Wilkes, and Yancey
127 (Figure 1; NCNHP 2016).

128



129
130

FIGURE 1. COUNTIES IN NORTH CAROLINA WITH RECORDS OF BOG TURTLES.

4

¹ Indicates counties where an alive bog turtle has not been found in recent surveys (i.e., last 15 years, from 2002-2017)

² Indicates counties that only have single road records and/or sites with only 1 turtle ever captured.

131 Surveys for the species have occurred regularly since the mid-1970s in the state (Herman
132 2003). The southern population of bog turtle is federally listed as Threatened due to
133 Similarity of Appearance (T(S/A)) and state listed as Threatened. The NC Natural Heritage
134 Program categorizes *G. muhlenbergii* as S2 (State Imperiled; typically 6-20 occurrences or
135 few remaining individuals), with a global rank of G3 (Vulnerable – at moderate risk of
136 extinction; NCNHP 2016).

137
138 There are 162 confirmed occurrence records for the species in the state, 32 of which are
139 solely road records (no wetland habitat present in vicinity). In addition, 118 are records at
140 wetlands, seven are locations without any known wetland habitat, and five are locations
141 where the habitat (and often the exact location) is unknown. Of the 118 records at
142 wetlands, nine of those are known to have been mostly destroyed, with many more having
143 significant reductions in size or quality from destructive human activities. Many of the
144 wetland sites have not had a recent turtle record. In the last 20 years (1997-2016), 74 of
145 the wetland sites had at least one bog turtle captured, 32 had five or more turtles captured,
146 and only 25 had 10 or more turtles captured. In the past 10 years (2007-2016), only 49
147 wetland sites had at least one bog turtle captured, only 22 sites have five or more turtles
148 captured, and only 18 sites have 10 or more turtles captured. Thus, there are relatively few
149 robust bog turtle populations. Many of these populations are believed to be extirpated;
150 many have been surveyed with no turtles found. It is important to point out that some sites
151 have been studied extensively while others have been minimally surveyed. Substantial
152 changes in habitat have occurred at many sites. A 10-year mark-recapture study of 11 bog
153 turtle populations in New York indicated that bog turtle populations with as few as 15-20
154 females can persist as stable populations (Shoemaker et al. 2013). Although a full analysis
155 has not been completed yet, data suggest that there are a limited number of populations in
156 North Carolina estimated to have 15 or more adult females (NCWRC unpublished data).

157
158 In a recent analysis, adult survivorship of bog turtles in North Carolina varied from 0.855 to
159 0.942 among eight intensively sampled sites, all below a 0.96 adult survival estimate
160 documented for northern bog turtle populations (Tutterow et al. 2017; Shoemaker et al.
161 2013). Because these sites are considered to contain eight of the most robust known bog
162 turtle populations in the state, other populations in NC also likely exhibit relatively low
163 survival. Juvenile survivorship was evaluated at three sites that had adequate data and
164 varied from 0.510 to 0.68 with the lower survivorship of 0.510 occurring at a population
165 known to be in decline (Tutterow et al. 2017). We also observed a skew in age classes
166 across all but two sites, with populations dominated by older individuals and very few
167 juveniles (Tutterow et al. 2017). These estimates, along with other studies, suggest that
168 North Carolina bog turtle populations are likely declining and without additional efforts,
169 local and regional extirpations may occur (Pittman et al. 2011; Tutterow et al. 2017). As our
170 datasets on NC populations grow, NCWRC will be able to more thoroughly assess the
171 species' status based on the best available science.

172

173 **THREAT ASSESSMENT**

174 **Reason for Listing**

175 The USFWS listed the northern population of bog turtle as Threatened on November 4,
176 1997, and cited that the species "is threatened by a variety of factors including habitat
177 degradation and fragmentation from agriculture and development, habitat succession due
178 to invasive exotic and native plants, and illegal trade and collecting". The southern
179 population was simultaneously listed due to Similarity of Appearance to the northern
180 population of this species (USFWS 1997). In the Federal Register, the USFWS stated that
181 the following factors were the reasons they did not propose the southern population for
182 listing: "(1) the recent discovery of bog turtle sites in the Piedmont physiographic province
183 of North Carolina, well outside the species' previously known Appalachian Mountains
184 range; (2) limited information regarding threats; and (3) inadequate survey coverage
185 within the southern range. A comprehensive status survey of the southern population is
186 currently underway and is anticipated to be completed by December 1999. The Service
187 agrees that it is premature to draw any conclusions regarding the status of the southern
188 population until additional survey and threat information becomes available" (USFWS
189 1997). In 2003, a status report on the southern population was completed (Herman 2003).
190 In North Carolina, an additional 36 records in 10 counties were discovered, three of which
191 were new county records (Herman 2003). At the time, the author estimated that there
192 were 53 populations in the state, with 30 designated as "viable or potentially viable,"
193 distributed across a total of 21 counties in North Carolina (Herman 2003).

194
195 In the "Bog Turtle Northern Population Recovery Plan," which applies only to the northern
196 population, the following are cited as reasons for listing the species: 1. Continued loss,
197 alteration, and fragmentation of habitat, 2. Illegal trade and collection, 3. Inadequacy of
198 existing regulatory mechanisms to protect bog turtle habitat, and 4. Disease & predation
199 (USFWS 2001). Although this document was drafted for the Northern Population, it has
200 become evident in recent years that the species faces many of the same threats in the
201 southern U.S. (Tutterow et al. 2017). Relatively few bog turtle populations remain, and
202 most of those appear to be in decline. There is significant concern for this species in North
203 Carolina.

204 205 **Present and Anticipated Threats**

206 **Habitat loss and degradation**

207 Habitat loss and degradation occurs when a bog has been converted to another use such as
208 a pond, agricultural field, or urban area or when a remnant of the habitat remains but it is
209 reduced in size and/or ecological integrity. This habitat degradation can occur as a result of
210 human activities, such as draining and ditching, but also from canopy closure due to
211 vegetative succession, pollution from land-use activities in the surrounding landscape, and
212 encroachment of non-native invasive species, among others.

213
214 The wetlands that bog turtles inhabit in North Carolina are considered among the rarest
215 and most imperiled habitat types in the Southeast (Richardson and Gibbons 1993 and
216 references therein, Noss et al. 1995 and references therein, USFWS 2014b). As much as 80-
217 90% of these bog habitats are estimated to have been lost over decades of land-use

conversion (Weakley and Schafale 1994; Noss et al. 1995). Land was converted for a multitude of reasons, including agricultural, industrial, commercial, and residential development. Almost every remaining mountain bog shows evidence of past human manipulation. Many sites were ditched and drained for agriculture or livestock or flooded to form ponds or lakes. Most bogs and their hydrologic regime have been degraded through intensive efforts to increase the farmable area. Even where bogs remained relatively intact, they remain vulnerable to changes in the surrounding watershed that affect the habitat quality of each bog (USFWS 2014b). Another effect of habitat loss is that the bogs that remain are more isolated on the landscape, with metapopulations composed of fewer or only one remaining bog turtle population, so that the remaining populations are more susceptible to extirpation from stochastic events.

A large proportion of known bog turtle wetlands in North Carolina are still privately owned with no long-term protective measures in place. About 60% of the wetland sites with at least one bog turtle captured in the last 20 years (44 of 74 sites) do not have any protection (i.e., under conservation ownership, or easement). This leaves many sites vulnerable to future habitat loss through ditching, draining, and other harmful activities.

Vegetative succession

Due to historical landscape level changes, many of the factors that are believed to have kept wetlands open historically are gone or diminished. For example, bison, elk, beavers, natural fire or fires set by Native Americans, and undisturbed hydrology, have all been cited as playing a role historically in maintaining these wetlands in an open state (NCWRC 2015). Without these disturbances, bog turtle populations are threatened by habitat degradation from natural vegetative succession, whereby the herbaceous grasses, flowers, and shrubs are replaced over time by large shrubs, saplings, and eventually trees. Minimal sunlight reaches the ground. Bog turtles and other species that require more sunlight struggle to successfully nest, produce young, and find adequate sunlight for thermoregulation and other activities. More woody vegetation and a subsequent decrease in sunlight reaching the ground threaten the continuation of this species. With more woody plants, more water is transpired, contributing to a lower water table at some bogs (USFWS 2014b) and threatening the continued persistence of this species.

Development and changes in the watershed

Urbanization, from residential neighborhoods to commercial and industrial land uses, poses a threat to bog turtles. Some wetlands have been lost entirely to land conversion. More will be converted, and the remaining bogs will be subject to myriad side-effects of changes in the surrounding landscape. An increase in coverage of impermeable surfaces often leads to increased storm water run-off and erosion, as well as the presence of additional nutrients and pollutants from these urbanized landscapes. Water consumption from wells may also result in less groundwater available within these wetlands.

Agricultural activity within the watershed of a bog can also be detrimental (Gustafson and Wang 2002). Many mountain bogs that remain are downhill from pastures, agricultural fields, orchards, nurseries, and Christmas tree farms, all of which can result in increased

263 runoff of fertilizers and pesticides (USFWS 2014b). This increase in nutrients, toxins, and
264 sediments threaten the suitability for bog turtle habitat. Unaltered, bogs are generally
265 nutrient poor; thus, increasing the nutrients to these systems can have damaging effects on
266 native plants important to bog turtles, such as sphagnum moss (USFWS 2014b). One of the
267 benefits wetlands provide agricultural landscapes is water quality enhancement by
268 mitigating the amount of pesticides, fertilizers, etc. (Verhoeven and Setter 2010).
269 Unfortunately, these chemicals can still negatively impact the biota, including reptiles,
270 present in those landscapes. For example, de Solla et al. (2014) found that the soil fumigant
271 metam sodium caused complete mortality of snapping turtle (*Chelydra serpentina*) eggs,
272 even when used at 10% of the recommended dosage. These chemicals can even have effects
273 when they are present at sublethal concentrations. Organophosphate pesticides have been
274 found at sublethal concentrations in the southern Sierra Nevada foothills of California, an
275 area adjacent to prolific agriculture; western pond turtles (*Emys marmorata*) from this
276 region have significantly reduced activity of cholinesterase compared to turtles located
277 farther from this agriculture (Meyer et al. 2013). This reduced enzyme activity from chronic
278 exposure could possibly lead to reduced neuromuscular function or altered behavior
279 (Meyer et al. 2013). Another source of pollution to the bog stems from the influx of
280 sediments, which can result in a layer of mineral soil on top of the saturated, organic soils of
281 a bog. This mineral layer dramatically alters the habitat and can make it difficult for bog
282 turtles to access the saturated soils (Torok 1994, Feaga 2010).

283
284 Myriad issues stemming from changes in the watershed and within the bog can have
285 detrimental effects on the hydrology and the resident bog turtles (Torok 1994, Brennan et
286 al 2001, Feaga 2010). Highway construction and other development within the recharge
287 area of a bog turtle wetland reduces groundwater discharge to the wetland (Brennan et al.
288 2001). Other issues include increased stormwater and runoff into these wetlands, which
289 can lead to an increase in erosion problems such as channelization and head-cutting.
290

291 **Climate change**

292 Climate models predict a variety of different outcomes for North Carolina (deWan et al.
293 2010, NCWRC 2015). The timing, amount, and type of precipitation is expected to change,
294 but the precipitation predictions are still somewhat unclear for North Carolina (NCWRC
295 2015). Some models indicate that the amount of precipitation may not change, but the
296 intensity and duration of both storms and droughts will increase (NCWRC 2015). Changes
297 in storm intensity can increase the soil erosion potential and decrease the frequency of
298 groundwater recharge (Karl et al. 2009). Periods of drought and intense rainfall events are
299 both predicted to increase (NCDENR 2010, Schultheis et al. 2010). Intense rainfall events
300 would likely flood many bogs, leading to scouring and further increasing nutrient loads
301 (NCDENR 2010).

302
303 A recent study specifically aimed at predicting the effects of climate change on Southern
304 Appalachian bogs indicated that future climates are likely to affect them primarily through
305 the impacts of temperature and precipitation on sphagnum (Schultheis et al. 2010). Per
306 this study, temperatures may increase by 3.5 °C, but precipitation is only predicted to
307 increase slightly. Thus, with temperature increases outpacing increases in precipitation,

308 future climates are likely to exceed the temperature and precipitation thresholds for
309 sphagnum and inhibit sphagnum growth. Warmer temperatures also increase
310 decomposition, which could further decrease net sphagnum growth and release nutrients
311 (i.e., carbon and nitrogen) into the environment (Schultheis et al. 2010). Dominant
312 vegetation is likely to shift from sphagnum moss to woody shrubs because shrubs are
313 better able to handle drought and higher nutrient levels (Schultheis et al. 2010). Succession
314 of vegetation to shrubs is already a threat, as mentioned above, and climate change may
315 intensify the threat and need for management. Likewise, invasive plants are likely to
316 become increasingly prevalent in bogs as vegetation dominance shifts away from
317 sphagnum (NCDENR 2010).

318

319 **Illegal collection and trade**

320 Illegal collection of bog turtles poses a serious threat, although we do not know how often
321 it occurs in North Carolina or which sites have been targeted in the past, with one
322 exception. In 1989, a presumably large number of turtles were collected from a bog in
323 Henderson County, and turtles showed up on the illegal market in Ohio (D. Herman pers.
324 comm.). In the years since that site was poached, the bog turtle population has consisted
325 almost exclusively of old turtles, despite having high quality habitat. It has never recovered
326 into a site with a good mix of age classes, and we attribute that to the loss of many breeding
327 individuals from this poaching event (NCWRC unpublished data).

328

329 We do know that collection of turtles in North America for illegal trade has become a
330 lucrative business, and there are documented instances of many species of turtles being
331 illegally harvested with the purpose of sale into the black market (Christy 2008; Todd et al.
332 2010). There is evidence that people are seeking to purchase wild-caught or captive-bred
333 bog turtles as pets and will pay as much as \$5000 for one turtle (Turtle Survival Alliance
334 pers. comm. 2014; Grover Brown pers. comm. 2017). A simulation model looking at the
335 impact of removal of one adult turtle per year indicated that the study populations in New
336 York and Massachusetts would be devastated by this and thus, anti-poaching measures
337 would be warranted (Shoemaker 2011).

338

339 **Overgrazing**

340 In some bogs, low-intensity grazing is beneficial to maintaining the habitat as relatively
341 open (Tesauro 2002, Tesauro and Ehrenfeld 2007). Livestock grazing has played an
342 important role in some bogs at staving off successional processes and keeping invasive
343 plant species in check (Tesauro and Ehrenfeld 2007). Many of the sites that appear to have
344 the most robust populations have had repeated disturbance that maintained some open
345 areas, including grazing, prescribed burning, beaver activity, and/or mechanical removal. It
346 appears that many bog turtle populations begin to decline when plant succession is
347 allowed to occur. However, detectability likely decreases as habitat becomes more
348 structurally complex with taller vegetation, thereby confounding comparisons of capture
349 numbers between sites with regular disturbance, such as grazing, and those without it.
350 Although we assume detectability inversely correlates with increased vegetative cover,
351 unfortunately there have not been any published estimates of detectability in the
352 literature. The management techniques, intensity, and frequency of use of those techniques

353 should be developed specific for each bog turtle site given that each site and situation is
354 unique. For some bog turtle sites, grazing will be an important tool in the conservation and
355 management toolbox for bog turtles and for others, alternative management techniques
356 will be more appropriate.

357

358 Overgrazing can be detrimental to both plant and turtle populations. In their Biological
359 Opinion for the northern population of bog turtles, the U.S. Fish and Wildlife Service (2010)
360 defined overgrazing as occurring when grazers are stocked at too high a density (exceeding
361 0.75 animal units/acre usually). One animal unit equals the forage consumption of a
362 1000-lb grazer (USFWS 2010). For example, four sheep or five goats can be stocked per
363 acre, or one dairy cow can be stocked per two acres (USFWS 2010). However, this system
364 of determining grazing impact does not account for variation between grazing species and
365 breeds. For example, a horse eats more than a cow of equal weight, sheep eat a greater
366 variety of different plants, dairy cattle eat more than beef cattle, and goats and sheep tend
367 to avoid wet areas (Crawley 1983, Menard et al. 2002). Overgrazing can cause excessive
368 soil exposure, denuding of moss and herbaceous vegetation, and destruction of rare plants
369 found in bog turtle wetlands (USFWS 2001, 2010). In addition, intensive grazing can
370 increase nutrient loads in these habitats. The average beef cow has 12 bowel
371 movements/day, amounting to 23 kg of feces (Hoorman 2005). When stocked at low
372 densities, cattle have little effect on nutrient (e.g., nitrogen and phosphorus)
373 concentrations (Line et al. 2000, Capece et al. 2007). However, significant increases in
374 nutrient concentrations can occur when cattle are stocked at high density (Line et al.
375 2000). This increase in nutrient load into an otherwise nutrient-poor system, in
376 conjunction with soil disturbance, can facilitate invasion of the habitat by exotic vegetation
377 (USFWS 2001). Some of our sites in North Carolina have been grazed at higher levels than
378 recommended by the current Biological Opinion (USFWS 2010).

379

380 Several research topics related to grazing need to be explored in more depth. First,
381 research is needed to investigate and better understand the ideal density for maximizing
382 benefits while minimizing risks from overgrazing. Likewise, there is a belief that the cows
383 breaking up the soil surface is an essential part of a bog turtle's habitat needs, but research
384 is needed on this topic to gain a better understanding of the role this plays and to help
385 separate out the detectability factors from the population variables. Similarly, it is possible
386 that in sites with less than optimal springs, cattle help break through the dry surface on the
387 top to access the subsurface groundwater and soft mucky soils, but again, this needs to be
388 researched.

389

390 **Injury/death from animals**

391 Large animals within a bog present a potential threat to bog turtles. In many cases, a bog
392 turtle may get stepped on and simply pressed deeper into the mud, thereby escaping
393 serious injury. However, sometimes they do get injured from being stepped on by livestock.
394 Presumably, the heavier animals present the largest threat (e.g., cattle and horses rather
395 than goats or sheep). NCWRC has documented 18 injuries and three deaths of bog turtles
396 that were attributed to being stepped on by livestock due to the shape of the injury

397 (NCWRC unpublished data). These injuries were often described as “crushed.” In all cases,
398 these turtles were at sites that had cattle at the time.

399

400 **Vehicles**

401 Roads present a major threat to small animals, including turtles (Gibbs and Shriver 2002;
402 Aresco 2005; Marsh and Jaeger 2015). Beyond direct mortality, roads can have numerous
403 other deleterious effects, including behavioral effects, decreased dispersal between
404 habitats, reduced abundance, and loss of genetic diversity (Marsh and Jaeger 2015). Turtles
405 are certainly considered to be a slow-moving animal and mortality risks as high as 95% per
406 crossing attempt have been documented for turtles (Aresco 2005). We know that bog
407 turtles often attempt to cross roads because NCWRC has many documented records of bog
408 turtles being found dead, alive, and injured on North Carolina roads (NCWRC unpublished
409 data). NCWRC has a total of 62 records of bog turtles found on roads in the state (43 alive,
410 19 dead) from 1951 to 2016. Sometimes they are found next to a known site, and
411 sometimes there is no bog anywhere in the vicinity, and the turtle seems to be traveling
412 over land. When a small population is losing even one turtle a year to an adjacent road, that
413 may be too many. In this scenario, the population is likely in a slow decline from which it
414 would be difficult to recover. Long-term demographic studies of turtle populations have
415 indicated that as little as 2-3% annual mortality from road mortality is likely to cause
416 population declines (Gibbs and Shriver 2002). Likewise, on the landscape scale, reduction
417 of a population’s dispersal ability can slowly drive a metapopulation to extinction (Marsh
418 and Jaeger 2015).

419

420 Other vehicles and equipment, such as tractors and lawn mowers, can result in injuries and
421 death to turtles (Saumure et al. 2007, USFWS 2010). NCWRC and partners have captured
422 three injured and two dead bog turtles over the years that have long, deep injuries to the
423 shell that appear to be caused by a blade (NCWRC unpublished data). Sometimes they
424 recover and we recapture them with healed or healing injuries, but it is likely that some
425 injured turtles do not survive. It is likely that they also get crushed under this equipment as
426 it is driven in the fields surrounding wetlands and through the wetlands themselves. Bog
427 turtles have been documented spending time in the fields surrounding some wetlands
428 (Pittman and Dorcas 2009). Some farmers have shared that they take advantage of a drier
429 year to bush hog a wetland to keep it from getting too overgrown; it seems likely that some
430 bog turtles are crushed and injured from this.

431

432 **Barriers to movement**

433 It has been shown that roads, railroad tracks, and other anthropogenic habitat alterations
434 can serve as barriers to movement and even cause entrapment for turtles (Aresco 2005,
435 Kornilev et al. 2006, Pittman and Dorcas 2009). A telemetry study of bog turtles at a site in
436 North Carolina led to the discovery of the death of a bog turtle in a puddle adjacent to a
437 railroad track, with the authors proposing that the turtle perished due to difficulty with
438 crossing the railroad tracks to get back to the bog (Pittman and Dorcas 2009). In all
439 likelihood, anything within the landscape that is a barrier to movement or entraps bog
440 turtles in place could increase their stress and result in an inability to thermoregulate, and
441 thus is a threat to their survival. Additionally, the isolation of populations due to barriers

442 and loss of habitat limits gene flow and removes the benefits of a functioning
443 metapopulation. The key to turtle conservation is the maintenance of the health and
444 function of their metapopulations, which relates directly to the overall long-term viability
445 of a population (Frankham et al. 2002). This is especially important for bog turtles due to
446 their dependence on small, isolated, and often rare habitat patches, and their frequently
447 diminutive population sizes, making them naturally susceptible to local extirpations
448 (Frankham et al. 2002, Pittman et al. 2011, Apodaca et al. 2012).

449

450 **Prevention of beaver activity**

451 In a relatively unaltered landscape and watershed, beaver activity is a plus for bog turtles,
452 as it keeps some sections of a wetland complex open with mostly herbaceous and shrubby
453 habitat, and areas are periodically flooded and opened back up so that there is always
454 some suitable habitat for bog turtles. Bog turtles are adapted to being able to adjust their
455 habitat use based on changing hydrology (Sirois et al. 2014, McCoy 2016). Flooding
456 associated with beaver activity has also been found to be beneficial for spotted turtles
457 (Yagi and Litzgus 2012). A geomorphic study of a bog in western North Carolina indicated
458 that the wetland has existed since the terminal Pleistocene, although it has changed in form
459 over time (McDonald 2010).

460

461 Occasionally, beaver activity can be detrimental to a bog turtle population if a site is very
462 small and the entire wetland is flooded for long periods of time due to beaver activity
463 (Sirois et al. 2014). This scenario is typically observed when a wetland has been reduced in
464 size due to human activities and the surrounding landscape is altered. In this case, when
465 the beavers flood the wetland, the turtles may have nowhere suitable to go because the
466 surrounding landscape is developed and/or has no other suitable habitat available.
467 Flooding, whether from beaver activity or increased intensity of storms due to climate
468 change, could also affect nesting and hatching success. Zappalorti et al. (2015) found
469 several nests that were placed so low that the embryos had drowned.

470

471 **Disease**

472 Although there has not been a die-off of bog turtles in the south, dead turtles with no
473 obvious signs of predation are occasionally found during routine surveys (NCWRC
474 unpublished data). Nonetheless, the possibility of a disease having detrimental effects on
475 the species is of great concern, especially given the small size of these populations. Since
476 2009, there are several reports of sick and dead bog turtles being found, mostly in the
477 northern population. Some of the sick bog turtles had a grey or whitish substance or
478 discoloration, skin lesions, sloughing of skin, and loss of claws, toes, or limbs. A Health
479 Bulletin published by USFWS in 2014 mentions that 14 bog turtles were found dead at one
480 site in May 2014 in Pennsylvania and outlines protocols for decontaminating gear and
481 submitting specimens for testing (USFWS 2014a). Test results have not indicated one
482 causative agent, but a variety of potential factors include injury, infection, pneumonia, and
483 carcinoma. Of particular concern are *Mycoplasma* and *Ranavirus*, and the USFWS warns
484 biologists to be aware and take necessary precautions (2014). Pneumonia, likely caused by
485 bacteria (e.g., *Pseudomonas* spp. and *Aeromonas* spp.), has been documented as the
486 potential cause of death for two turtles in North Carolina and Virginia (Carter et al. 2005).

487 However, there are few data available on the typical microflora associated with wild bog
488 turtles (Brenner et al. 2002).

489

490 **Competition**

491 Although bog turtles in North Carolina often share habitat with snapping turtles (*Chelydra*
492 *serpentina*) and occasionally mud turtles (*Kinosternon subrubrum*), competition has not
493 been directly confirmed. A study conducted in Maryland found that there was substantial
494 overlap between the area of a wetland used by spotted turtles and the area of the same
495 wetland used by bog turtles (Dinkelacker et al. 2000). More specifically, the area of overlap
496 between spotted and bog turtles constituted 79.6% of the total area used by bog turtles,
497 but only 19.5% of the total area used by spotted turtles (Dinkelacker et al. 2000).

498 Presumably, since these two species were overlapping in the same wetland, interspecific
499 competition would at least be possible, but this was not tested. Spotted turtles (*Clemmys*
500 *guttata*) have not been observed in any of the North Carolina sites. Mud turtles are found in
501 some of the Piedmont bog turtle sites, and are absent or in lower numbers in sites within
502 the Mountain Region. Elevation and temperature, rather than competition, may be factors
503 that favor bog turtles over mud turtles at most sites.

504

505 A study in Pennsylvania looked at early (fall) and delayed (spring) emergence of hatchlings
506 of snapping, painted (*Chrysemys picta*), spotted, wood, bog, and stinkpot (*Sternotherus*
507 *odoratus*) turtles occupying the same wetland from 1965-1985 (Lovich et al. 2014). They
508 observed that snapping, painted, and spotted turtles were facultative delayed emergers,
509 and most individuals emerge in the spring, whereas wood, bog, and stinkpots were obligate
510 early emergers. They suggested that the obligate early emergence could be a means of
511 reducing competition with species that predominantly emerge in the spring (Lovich et al.
512 2014). However, most of these species don't overlap with bog turtles in North Carolina so it
513 is difficult to deduce the influence of competition. Bog turtles are likely competing with
514 other species for resources or habitat, but there has not been any research yet that directly
515 evaluated and/or confirmed this, especially in the southern population.

516

517 **Predation**

518 Data suggest that low nest success and juvenile survival may be an important limiting
519 factor for turtles in general (Congdon et al. 1983) and specifically for bog turtles in North
520 Carolina (Tutterow et al. 2017). Limited research has been conducted on nesting, hatchling,
521 and juvenile bog turtles due to the secretive nature of these age classes. Zappalorti et al.
522 (2004) documented 14-59% hatch success for naturally incubated nests at five
523 Pennsylvania sites. Of these nests monitored, the predation rates were 12-57%. The
524 authors suggest that predation limits bog turtle nest success at some sites. A recent
525 Maryland predation study observed approximately 40% of eggs depredated at one site and
526 as many as 74% at another over a two-year period (Byer 2015). Additionally, Macey (2015)
527 documented a 62% predation rate over a four-year period at 24 unprotected nests across
528 nine sites in southeastern New York. Several studies have substantially linked turtle nest
529 predation rates to the landscape matrix (Kolbe and Janzen 2003, Marchand and Litvaitis
530 2004). Human-commensal predators such as Northern raccoons (*Procyon lotor*), striped
531 skunks (*Mephitis mephitis*), and red foxes (*Vulpes vulpes*) are likely to represent the largest

532 sources of increased predation in altered habitats (USFWS 2001). The following species are
533 known or suspected predators of bog turtles: canids (*Canis familiaris*, *C. latrans*, *Urocyon*
534 *cinereoargenteus*, *Vulpes vulpes*), egrets and herons (Ardeidae), minks (*neovison vison*),
535 muskrats (*Ondatra zibethicus*), opossums (*Didelphis virginiana*), raccoons (*Procyon lotor*),
536 skunks (*Mephitis mephitis*, *Spilogale putorius*), snakes (e.g., *Coluber constrictor*,
537 *Lampropeltis getula*, *Nerodia sipedon*, *Thamnophis sirtalis*), and snapping turtles (Ernst and
538 Lovich 2009 and references therein). A study currently underway in North Carolina is
539 examining the effects of predation on nesting success across multiple bog turtle sites and
540 those results will be helpful in gaining a better understanding of the influence of predation
541 on bog turtles.

542

543 It is important to mention that domesticated pets may pose a serious problem for bog
544 turtles, primarily house cats (*Felis catus*) and dogs (*Canis familiaris*). Many bogs are located
545 within a fragmented and developed landscape with residential areas, and thus, a source of
546 cats and dogs that may be allowed to roam. House cats, both pets and feral, are significant
547 predators on wildlife, especially small mammals and birds (Loss et al. 2013). Few data are
548 available on their impact on herpetofauna, but Loss et al. (2013) estimated that annually
549 86-320 million amphibians (median 173 million) and 228-871 million reptiles (median 478
550 million) are killed by house cats in the continental U.S. Likewise, dogs in Mexico have been
551 observed digging up and scavenging sea turtle nests, and this behavior was positively
552 correlated with insufficient food provision by owners (Ruiz-Izaguirre et al. 2015). Dogs can
553 also alter the behavior of wildlife. In parks and recreation areas, the presence of dogs has
554 been shown to significantly reduce the activity of deer and small mammals, and increase
555 the activity of some wild carnivores, especially other canids (Lenth et al. 2008). If the
556 current study does not elucidate the degree of threat that this poses to bog turtles, further
557 research may be needed to get a better understanding. Anecdotal accounts of trained
558 tracking dogs having difficulty locating bog turtles within a wetland indicates that
559 domesticated dogs may not be a primary threat to bog turtle nests (pers. comm. Thomas
560 Thorp), but further investigation would be helpful.

561

562 In the North Carolina Bog Turtle Database, NCWRC has documented 24 injured and two
563 dead turtles from bites, presumably a mix of native predators and domesticated pets
564 (2017). Two additional turtles were known to be injured by a pet that had entered the bog,
565 both dogs—one that was a private landowner's pet and another that was being trained to
566 find turtles for scientific purposes (NCWRC unpublished data).

567

568 **Invasive species**

569 In general, wetlands are especially vulnerable to invasions by aggressive plants. Less than
570 6% of the land on Earth is wetlands, but 2% of the most invasive plant species are wetland
571 obligates (Zedler and Kercher 2004). The accumulation of debris, sediments, water, and
572 nutrients in wetlands helps facilitate invasions by creating canopy gaps, accelerating the
573 growth of opportunistic plant species, and through direct input of invasive seeds (Zedler
574 and Kercher 2004). To make it worse, many invasive wetland species grow as a monotype,
575 resulting in lower biodiversity, altered habitat structure, and modified food webs (Zedler
576 and Kercher 2004).

577

578 In North Carolina mountain bogs, NCWRC has documented many non-native invasive
579 species, including autumn olive (*Elaeagnus umbellata*), Chinese lespedeza (*Lespedeza*
580 *cuneata*), Chinese privet (*Ligustrum sinense* and *L. vulgare*), Chinese silvergrass (*Miscanthus*
581 *sinensis*), Japanese barberry (*Berberis thunbergii*), Japanese honeysuckle (*Lonicera*
582 *japonica*), Japanese knotweed (*Polygonum cuspidatum*), Japanese stiltgrass (*Microstegium*
583 *vimineum*), multiflora rose (*Rosa multiflora*), oriental bittersweet (*Celastrus orbiculatus*),
584 purple loosestrife (*Lythrum salicaria*), reed canarygrass (*Phalaris arundinacea*), and yellow
585 flag iris (*Iris pseudacorus*), among others. In some cases, these invasive plants are a small
586 component of a wetland and appear to make little difference in the habitat structure and
587 ecosystem functioning, though this has not been researched in any detail. There are several
588 documented cases of invasive plant species forming a monotype in a bog and affecting the
589 habitat quality for bog turtles in other states (e.g., Blossey 2002, Warwick 2014).

590

591 Wildlife not native to the bog may also pose a threat to bog turtles, especially any species
592 that affects nest success and juvenile or adult survivorship. One animal of particular
593 concern is the red imported fire ant (*Solenopsis invicta*). This species has been documented
594 in 73 of North Carolina's 100 counties, eight of which are counties with bog turtle records
595 (Burke, Cherokee, Clay, Gaston, Graham, Iredell, Macon, and Rutherford) (NCDA&CS 2017,
596 NCWRC unpublished data). To our knowledge, the fire ant has not been documented
597 present within a bog in North Carolina, but this species could pose a serious concern to bog
598 turtles should it begin invading the bog or perimeters of bogs. Fire ants have been
599 documented preying upon nests of gopher tortoises (*Gopherus polyphemus*), snapping
600 turtles (*Chelydra serpentina*), Florida cooters (*Pseudemys floridana*), and yellow-bellied
601 sliders (*Trachemys scripta scripta*) in the wild (Allen et al. 2004; Aresco 2004). Turtles are
602 particularly vulnerable once an egg is pipped and if the species exhibits delayed emergence
603 (Allen et al. 2004). While eggs are intact, the hardness of the shell influences whether or not
604 fire ants can penetrate them. For example, fire ants were not able to penetrate the harder
605 shelled eggs of musk turtles (*Sternotherus odoratus*) or Florida softshell turtles (*Apalone*
606 *ferox*), but could penetrate the softer eggs of Eastern painted turtles (*Chrysemys picta picta*)
607 and yellow-bellied sliders (Diffie et al. 2010). Fire ants have been documented as predating
608 on unhatched spotted turtle (*Clemmys guttata*) eggs in captivity (Herman 1987). Given
609 what we know about the aggressive behavior and their proclivity to invade newly
610 disturbed areas, fire ants should be of great concern when it comes to these fragile
611 ecosystems and communities, especially in light of the vulnerability of bog turtle nests and
612 the small size of juvenile turtles.

613

614 **Summary of Threats**

615 The threats outlined above include habitat loss and degradation, vegetative succession,
616 development and changes in the watershed, climate change, illegal collection and trade,
617 overgrazing, injury/death from animals, vehicles, barriers to movement, prevention of
618 beaver activity, disease, competition, predation, and invasive species. Many of these threats
619 influence or are somehow interconnected with others, but this list encompasses all known
620 or suspected threats to bog turtles and/or their habitat to some degree. Likewise, the
621 degree of threat from some of these is largely unknown. Research and time may elucidate

622 and fill in some of these information gaps, but in the meantime, we must proceed and act
623 with the best available data and information. Given our current knowledge of these threats
624 and due to limited resources, it is important to recognize which threats are of greatest
625 concern to bog turtles and their habitat in North Carolina. Major threats include vegetative
626 succession, vehicles, habitat loss and degradation, predation, development and changes in
627 the watershed, and barriers to movement. These threats comprise most of the problems for
628 bog turtles, though the others certainly play a role and should definitely be considered and
629 incorporated into any action plans. Threats to keep a keen eye on include illegal collection
630 and trade, disease, and invasive species as these could have a large negative impact in a
631 short time if anything new develops. Climate change is another threat that could have a
632 negative impact and thus, it is essential to consider this in all other planning for bog turtles
633 and their habitat. Lastly, more research is needed to better understand the extent of threat
634 that many of these issues pose. As we learn more, NCWRC will need to adapt our strategies
635 accordingly.

636

637 **Historic and Ongoing Conservation Efforts**

638 There is a long history of bog conservation efforts by a diverse partnership in western
639 North Carolina. Partners include Project Bog Turtle (PBT), NCWRC, U.S. Fish & Wildlife
640 Service (USFWS), U.S. Forest Service, Natural Resources Conservation Service (NRCS), The
641 Nature Conservancy (TNC), NC State Parks, NC Natural Heritage Program, Carolina
642 Mountain Land Conservancy (now, Conserving Carolina), Blue Ridge Conservancy, National
643 Park Service, Catawba Lands Conservancy, and private land owners. Bog turtle research in
644 the state began in the 1970's by Robert Zappalorti and Dennis Herman. In the late 1980's,
645 several other NC Herpetological Society members, including Jeff Beane and Thomas Thorp,
646 began to assist with bog turtle surveys. In 1995, Project Bog Turtle was established and has
647 been dedicated to monitoring and conserving bog turtles and protecting bog turtle habitat
648 in North Carolina ever since. The North Carolina Wildlife Resources Commission has taken
649 a lead on bog turtle efforts in the state more recently and works closely with Project Bog
650 Turtle, the US Fish and Wildlife Service, and all the above-mentioned partners.
651 Collaboration and communication between these groups is essential to meeting
652 conservation goals for the bog turtle in North Carolina.

653

654 Project Bog Turtle hosts an annual meeting at which all states in the range of the southern
655 population share information and coordinate activities. This group and other partners have
656 accomplished a great deal for bog conservation over the last 25 years, including land
657 acquisition at 26 bog turtle sites across western North Carolina, initiation of restoration
658 efforts at numerous sites, and management of many sites. Other conservation activities by
659 partners include education of land owners, nest protection, and management of beavers
660 when flooding is an issue. Partner programs such as the USFWS Partners for Fish and
661 Wildlife and NRCS Wetlands Reserve Easement and Environmental Quality Incentives
662 Program can also provide incentives to private landowners to protect and manage bogs.

663

664 A new tool was added to the bog conservation toolbox in 2015, with the establishment of
665 Mountain Bogs National Wildlife Refuge. The refuge will complement and expand existing
666 conservation efforts by offering additional opportunities to protect sites via fee title or

667 conservation easement and other avenues such as landowner management agreements.
668 Additionally, a new partnership, the Bog Learning Network, was formed around the same
669 time. The Bog Learning Network is modeled after the successful Fire Learning Network and
670 is a consortium of scientists and land managers working to advance the restoration and
671 management of Southern Appalachian Bogs.

672
673 Despite these accomplishments, land protection and active, long-term management are still
674 needed at most the remaining mountain bog sites. While portions of some bogs have been
675 conserved and a few bogs are protected in their entirety, most sites are still in private
676 ownership and lack any protection. Of the 74 wetland sites with at least one bog turtle
677 captured in the last 20 years, 44 are not protected (i.e., under conservation ownership or
678 easement). Of the 18 sites that have 10 or more turtles captured over the last 10 years, 8
679 are privately owned without any protection. Landowner relationships are paramount to
680 our success in studying, managing, and protecting the wetland the bog turtles inhabit.

681
682 Newly emerging partnerships across the species' range and within the southern population
683 have the potential to aid in conservation efforts in North Carolina. NCWRC and USFWS
684 biologists in North Carolina have begun to work more closely with biologists that work
685 with bog turtles within the northern population. Likewise, discussions began recently
686 about developing a regional bog turtle conservation plan for the southern population,
687 which could be helpful in gaining additional funding for bog turtle conservation in the state.

688 689 **CONSERVATION GOALS**

690 The conservation vision for *Glyptemys muhlenbergii* is to protect and restore the
691 populations and habitat of this species to prevent extirpation and ensure long-term
692 viability across its current range in North Carolina for the next 100 years. NCWRC will work
693 with our partners to achieve the following goals:

694 695 **Goals**

- 696 A. Identify threats to bog turtle populations
 - 697 A1. Improve knowledge of threats
 - 698 A2. Conduct a site-specific threat assessment
- 699 B. Maintain and maximize the number of viable populations
 - 700 B1. Address threats
 - 701 B2. Protect habitat
 - 702 B3. Manage habitat appropriately
 - 703 B4. Restore degraded habitat
 - 704 B5. Manipulate populations when beneficial
- 705 C. Further our knowledge about bog turtles
 - 706 C1. Fill in information gaps about distribution in the state
 - 707 C2. Monitor populations to determine status and trends
 - 708 C3. Conduct research to improve our understanding of bog turtle ecology
- 709 D. Expand outreach efforts
 - 710 D1. Involve more collaborators
 - 711 D2. More effectively reach landowners

712 **CONSERVATION ACTIONS**

713 **Goal A: Identify Threats to Bog Turtle Populations**

714 The more we understand about the threats that bog turtles face, the more effective and
715 efficient our conservation decisions can be. We need to learn more about the known and
716 unknown threats to bog turtles, and assess and rank the threats on a site-specific basis.

717 **A1. Improve Knowledge of Threats**

718 We know quite a bit about the threats to bog turtles, but much is still unknown, especially
719 in terms of the extent of impact from several threats. A first step is to continue learning
720 more about these stressors through monitoring and targeted research. This can be done by
721 studying specific populations to better understand what is shaping that population.

722 Another angle is to learn more about the degree of impact of specific threats, such as road
723 mortality, illegal collection, disease, grazing, and predation, on these populations. Through
724 this process, we will develop a more thorough assessment of threats to bog turtles in North
725 Carolina. This will be a valuable tool as we are making conservation and management
726 decisions in the future. As part of this threat assessment, we need to gain a better
727 understanding of which management actions may be most effective and economical to
728 address these threats.

729 **A2. Conduct a Site-specific Threat Assessment**

730 In order to make educated management decisions on the ground, we need to have site-
731 specific information about threats. We will rank the known threats for each site based on
732 the best available data and information for each extant bog turtle population. Whenever
733 possible, we will also attempt to determine the degree of influence of threats to the site. For
734 example, at one site, the threat ranked #3 could be a huge threat to that population,
735 whereas at another site the threat ranked #3 could be having a minuscule impact. To
736 accomplish this site-specific assessment, we will need to visit sites to assess the current
737 situation, conduct a GIS analysis, and spend time organizing this information into a user-
738 friendly format. Our initial focus will be on the Tier 1 and Tier 2 sites (see Goal B).

739 **Goal B: Maintain and Maximize the Number of Viable Populations**

740 A single population will be considered viable if it is estimated to have 1) *at least 15 female*
741 *adult turtles found within past 10 years* (Shoemaker et al. 2013) AND *all age classes have*
742 *been observed in the past 10 years* (eggs, hatchlings, juveniles, and adults). We propose the
743 following categories related to viability: non-viable, unknown viability, potentially viable,
744 and viable.

745 Maintenance of viable bog turtle populations will necessitate a multitude of strategies and
746 actions. NCWRC will need to rank all known extant populations from most to least viable.
747 This will be accomplished through an objective and data-based method that considers
748 survivorship, number of captures, life stages represented, and other factors. Very few
749 populations are truly viable (Tutterow et al. 2017), so it will help to focus on a subset of 10
750 sites at a time. Initially most effort will go towards maintaining the 10 “best” populations

753 ("Tier 1") in the state as viable (population stable or increasing) for the long-term. In the
754 meantime, some actions may be needed to help keep other populations from being
755 extirpated or undergoing extreme population declines. Once the Tier 1 populations are
756 deemed viable and stable and an organized plan is in place for maintaining their viability,
757 the focus will shift to the next 10 "best" populations ("Tier 2"). Once the Tier 2 populations
758 are deemed viable, NCWRC will shift focus to the next 10 populations ("Tier 3") and so on,
759 until NCWRC has made our way through all known extant populations.

760
761 Once the Tier 1 populations have been identified, the optimal strategy for maintaining or
762 restoring a viable population can be developed for each one. Ensuring NCWRC has a set of
763 populations that are stable or increasing is an important first step towards minimizing the
764 chances of this species being fully federally listed or becoming regionally extirpated in
765 North Carolina. Also, through this process NCWRC will learn more about the most efficient
766 and cost-effective way to move a population from "declining" to "stable or increasing", and
767 this will aid us in the restoration, management, and protection of additional populations.
768

769 A variety of actions will need to be used as we are working towards meeting this goal, with
770 some actions more central and others more peripheral, yet still important. Population
771 monitoring, habitat management, targeted research, and implementing actions to address
772 threats at a specific site are the most integral strategies to this process. However, other
773 actions that also play a role in the success of meeting this goal include habitat protection,
774 population manipulation, law enforcement, and disease abatement efforts.
775

776 **B1. Address Threats Specific to each Site**

777 Once we know the threats and issues that each site faces, NCWRC will devise a plan and
778 implement activities with the aim of improving the viability of a population. In some cases,
779 we may need to take action before we fully understand the situation. The response needed
780 to address each threat, should it be identified or suspected as a problem at a given site, is
781 described in the list below, however note that this list is 1) not exhaustive, and 2) based on
782 current knowledge and subject to change:
783

784 *Habitat loss and degradation:*

- 785 - Protect remaining bogs and the surrounding landscape through fee-simple
786 purchase, donations, conservation easements, and other protective means.
- 787 - Through permit-reviews (e.g., NCWRC, USFWS) and enforcement of current
788 regulations (e.g., USACE, EPA, NCDEQ), protect bogs from further destruction and
789 degradation (e.g., filling, ditching, flooding to create ponds).
- 790 - Consider proposal of additional regulations to protect our remaining mountain bogs

791 *Vegetative succession:*

- 792 - Create a map of the different vegetative zones of the wetland and surrounding
793 landscape and place points or polygons on the map to indicate where different
794 known habitat features are (nesting areas, hibernacula, springs, etc.). Then begin
795 devising a plan for each of the zones, with the aim of providing all critical bog turtle
796 habitat needs somewhere in the wetland (shrubby area for shade, open sunny area
797 with short herbaceous vegetation for basking and nesting, areas with deep mud for

- 798 overwintering, food sources within or on perimeter of wetland, area with thick
799 vegetation for hiding, multiple areas with surface saturation, etc.).
800 - As part of the plan for each zone and based on the scientific literature and recent
801 research results, determine what the most appropriate technique to use is (e.g.,
802 grazers, mechanical vegetation removal, prescribed fire).
803 - Develop a management schedule (manual shrub thinning and herbicide application,
804 grazing, burning, etc.) for all extant population, beginning with the Tier 1 and 2 sites.
805 This schedule will be adaptive in regard to meeting site specific needs.
806 - Partner with agencies that have programs that facilitate habitat management on
807 private property, including NRCS and USFWS Safe Harbor Agreements

808 *Development and changes in the watershed:*

- 809 - Purchase or protect surrounding landscape when feasible to mitigate detrimental
810 changes in the watershed.
811 - Through attentive permit review, make recommendations that reduce storm water
812 runoff, decrease impermeable surface area, and support measures that increase
813 infiltration into the groundwater.
814 - Partner with NRCS and USFWS programs to aid in reducing agricultural runoff into
815 wetlands.
816 - Educate adjacent landowners about water conservation when appropriate.
817 - Partner with a hydrologist to better understand the hydrology of each site, to map
818 springs, understand flow regimes, and potential threats are to the hydrology.

819 *Climate change:*

- 820 - Prioritize protection of bogs that have multiple and productive springs as these
821 wetlands have the best chance of remaining saturated enough for bog turtles when
822 droughts occur.
823 - Protect surrounding landscape so that the negative effects of intense rainfall events
824 are lessened due to water infiltration and the ability to address runoff issues.
825 - Be prepared to increase the frequency of management activities targeted at woody
826 stems and invasive plants, as these are likely to fare better under most predicted
827 climate change scenarios.
828 - Devise ways to help protect the diverse sphagnum species from reduction and die-
829 off with increased temperatures and higher nutrient levels.

830 *Illegal collection and trade:*

- 831 - Step up enforcement efforts by state and federal officers, including patrolling near
832 the Tier 1 and 2 sites and any others deemed vulnerable to illegal collection.
833 - Foster stronger relationship between biologists and enforcement officers across the
834 state, but especially those that work in western North Carolina and the Piedmont
835 counties with records of the species.

836 *Overgrazing:*

- 837 - When grazing exceeds 0.75 animal units/acre, talk with the landowner to see if
838 there is a potential solution that would lessen the intensity of the grazing, especially
839 during the bog turtle mating and nesting season (May-September).
840 - When possible, pursue funding to set up a fence with strategically located access
841 gates (for cows and humans) that allows for seasonal grazing of the wetland.
842 Conservation partners such as USFWS and NRCS may be able to assist with funding
843 and implementation of this.

- 844 - When appropriate, set up grazing lease agreements on properties that are state or
845 federally owned to ensure that sites continue to provide suitable habitat (not too
846 shaded and not overgrazed). These lease agreements may include seasonal
847 components if that is deemed important for the bog turtle population.
848 - When the plant community or topography of a site is deemed too sensitive for heavy
849 grazers or any grazers at all, move on to other methods of habitat management.

850 *Vehicles:*

- 851 - Educate landowners about ways to minimize injuries/deaths of bog turtles from
852 mowing and bush hogging in the vicinity of bog turtle habitat. Discourage them from
853 bush hogging in the wetland and offer to assist in doing that work by hand.
854 Encourage them to raise the blade level as high as possible and to leave a buffer that
855 is rarely disturbed between the wetland edge and agricultural crops. Encourage
856 them to mow when turtles are less likely to be in the field (e.g., during heat of the
857 day in summer).
858 - Protect property so that the use of heavy equipment in or near bogs can be
859 eliminated or minimized.
860 - Form a task force to address issues of roads and determine a multi-faceted plan for
861 dealing with this issue. This will include addressing this issue at sites we know or
862 suspect bog turtles are impacted the most by road mortality/injuries. An important
863 partner in this task force is the North Carolina Department of Transportation (NC
864 DOT).

865 *Injury/death from Grazers:*

- 866 - If a site is overgrazed, take steps as possible to reduce the intensity of grazing in the
867 wetland (See Overgrazing section above).
868 - If a site is on the brink of a local population extirpation, consider whether the
869 potential costs of grazing are outweighing the benefits when the loss of one turtle
870 may have a huge detrimental effect on the continuation of the population.

871 *Barriers to movement and stress*

- 872 - The task team addressing issues with transportation infrastructures will include this
873 in their discussion and planning.

874 *Prevention of beaver activity:*

- 875 - Educate landowners and managers on the benefits of beaver activity in bogs when it
876 is occurring in a relatively undisturbed landscape with multiple areas and all
877 essential habitat needs met even with some flooding.
878 - Work with private landowners to find a balance between their needs and allowing
879 the beavers to remain and provide ecological benefits.

880 *Disease:*

- 881 - Form a task team to address disease concerns and develop protocols for handling
882 disease cases and preventing spread of parasites and pathogens from one site to
883 another. Use sources that already exist (e.g., SEPARC disease task team reports, Bog
884 Learning Network Decontamination Protocols) as a starting point.

885 *Competition:*

- 886 - Given that experts see this topic as a minor threat relative to other issues, NCWRC
887 will likely not set specific objectives to mitigate competition, especially since this is
888 presumably a natural aspect of the bog turtle's ecology. At some point, research
889 could be done to examine how much competition there is, from what species, and

890 what effect it has on the bog turtle population, but this is a low priority research
891 question currently.

892 *Predation:*

- 893 - Additional research is needed to determine which sites are threatened by predation
894 issues and to characterize the extent of this problem. Although predation is a part of
895 the ecology of bog turtles, some populations are in such peril that action is needed to
896 give the population a boost.
897 - When a predator issue is identified, an action plan should be devised. The plan of
898 action will be tailored to the particular site and management options that are
899 available. At some sites, a single predator may need to be removed from the
900 property, and in other cases it could be much more complex and may require other
901 techniques. Techniques that may be employed include trapping and humane
902 euthanasia of the problematic individual predators and protection of nests via
903 predator excluder cages. In most cases, it will be necessary to monitor the situation
904 after taking action in order to see if the problem has been fully addressed or
905 whether we need to adapt the plan. Predator removal is not always appropriate and
906 may not be effective in some situations.
907 - Education of adjoining landowners when feral pets have been identified as a
908 problem. This need may include knocking on doors and talking with landowners and
909 possibly handing out brochures or providing educational programs in the
910 community.

911 *Invasive species*

- 912 - Incorporate treatment and removal of invasive plants into site-specific Management
913 Plans that are being written.
914 - Develop a plan for surveying for and eradicating invasive plant species when they
915 are first found and have not spread far. This strategy is especially important for
916 species that have proven to dramatically alter the structural integrity of a bog turtle
917 site and that are particularly difficult to eradicate/treat (e.g., reed canarygrass,
918 purple loosestrife).
919 - Develop a response plan to prepare for the discovery of fire ants at a bog turtle
920 wetland.

921 **B2. Protect Habitat**

922 In conjunction with partners and working with willing landowners, NCWRC will aim to
923 protect all known bog turtle populations through permanent conservation easement, fee-
924 simple purchase or donation, or some other form of permanent protection with 20
925 populations as the initial goal. NCWRC will make protection of the Tier 1 sites a priority and
926 secondarily, the Tier 2 sites. These are our most important bog turtle populations and
927 without protection, all our other efforts could be in vain. NCWRC will only be working with
928 landowners that have voluntarily expressed an interest in acting to protect a bog. Our
929 strategy will require developing a prioritized list of all the sites that we would like to have
930 protected as well as a concerted effort to reach out to landowners and ask for their interest
931 in selling or setting up an easement or taking other protective action, such as registration
932 under the NCNHP Registered Heritage Area program or permanent easements through

934 NRCS. When conservation easements are set up, we will make sure that the language in the
935 easement document allows for appropriate management of the bog turtle habitat.

936
937 The initial planning list will have more than 20 sites so that NCWRC can identify 20 that
938 have landowners willing to cooperate in site protection. It would be ideal to maintain
939 relationships with all landowners that have bogs on their property and convey to them that
940 we are interested in purchasing their property if they are ever interested in selling.
941 Although some landowners may not currently be interested in selling or setting up an
942 easement, they may be interested in the future. It will take time and patience to keep these
943 key relationships with families so that NCWRC is in a position to act to protect bog habitats
944 when opportunities arise. Hopefully, some of these sites will be the ones identified above.
945

946 NCWRC has identified bog turtle metapopulations in the state and from that list, NCWRC
947 will create a ranked list of sites from most to least functional as a metapopulation.
948 Ultimately, we would like to see all metapopulations protected, but our initial goal and
949 focus will be on the top 5 best metapopulations. NCWRC will make a concerted effort to
950 protect, appropriately manage, and when necessary, restore these metapopulations.
951 NCWRC will also attempt to protect the land between these metapopulations, especially
952 rivers and streams and their associated riparian areas, as well as any undeveloped
953 terrestrial land that lies between the bogs that make up a metapopulation. Through
954 partnerships with land trusts, other agencies, and private landowners, NCWRC will attempt
955 to protect as many of the wetlands and land between them in each of these 5
956 metapopulations. The regional land trusts will play a critical role in developing
957 relationships with additional landowners and assisting in an educational campaign in the
958 communities closest to these metapopulations.

959
960 Protecting the actual wetland is the first priority, but NCWRC will also strive to protect
961 additional land because this is critical for habitat quality and suitability for bog turtles.
962 Other target lands for protection will include the land immediately surrounding the
963 wetland, the entire watershed that feeds the wetland, the land between wetlands, and any
964 other lands/wetlands that would have a benefit to the population or metapopulation.
965 Protecting the watershed is critical and key components for this include inclusion of
966 riparian buffers, minimization of impervious surfaces, and limiting activities that involve
967 water extraction. When possible, NCWRC will also protect the upland, wetland, and stream
968 habitat between bogs and within all identified bog turtle metapopulations in order to
969 maintain or improve movement corridors, habitat connectivity, and gene flow. Any
970 additional protection is considered positive.

971

972 **B3. Manage Habitat Appropriately**

973 NCWRC will draft management plans for bog turtle sites, prioritizing sites that have
974 complex and immediate management needs, a bog turtle population that would benefit, and
975 that we have permission to manage (i.e., state, federal, or NGO owned, or with permission
976 from a private landowner). NCWRC will collaborate with partners to draft these plans. The
977 full suite of management and conservation tools that are available will be considered in
978 development of these plans. The habitat and threats that each site faces are site-specific,

979 and thus, different tools and techniques will be appropriate and suitable for any one site.
980 Conservation and management tools to be considered include mechanical thinning and
981 removal of vegetation, treatment of invasive plants, prescribed fire, use of herbicide for
982 treatment of invasive native and exotic plants, hydrologic restoration (e.g., plugging ditches,
983 fixing head-cuts, breaking up drain tiles, removal of fill dirt), population manipulations (e.g.,
984 head-starting, re-introductions), use of grazers/browsers (e.g., cattle, goats, bison), planting
985 of desirable native plants, and any others deemed to have utility for accomplishing our
986 goals.

987
988 Each of the Tier 1 and Tier 2 sites should be evaluated to determine if any habitat
989 management is needed at those sites to ensure that all of the essential components of
990 suitable habitat are present (see "Life History and Habitat" section), and that it is of
991 adequate size and quality. If any essential components are missing, then the plan of action
992 moving forward should be to take action on anything that has minimal risk to the turtles
993 with a good chance of a neutral or positive outcome, even if a Management Plan has not
994 been written for that site. It is important to take actions with little risk now, rather than
995 watch a population decline over time while waiting for a polished plan. Once habitat
996 management has been conducted, rigorous population and habitat monitoring, and possibly
997 even research (e.g., radio-telemetry) will indicate if the efforts taken are making a
998 difference.

999
1000 NCWRC will also work towards establishing a prioritized schedule for habitat management
1001 of all extant bog turtle populations. The schedule's purpose is to help organize and
1002 prioritize what needs to be done and to determine what is realistic given our resources. In
1003 this schedule, NCWRC will identify needs related to that schedule, including staff capacity,
1004 partners that will be involved, funding needed, and anything else required to carry out the
1005 habitat management plan. From there, NCWRC will reach out to partners for assistance in
1006 implementing these management activities. Another important aspect of generating this
1007 schedule is to incorporate monitoring into the schedule for each site that is on the schedule
1008 for being managed.

1009
1010 Another important effort will involve habitat management of all the wetlands that are part
1011 of the five priority metapopulations that have been identified, whenever landowners are
1012 willing and the funding is available. Even if all the wetlands in a metapopulation do not
1013 have records of bog turtles, those habitats should be managed and restored whenever
1014 possible with bog turtles' needs in mind.

1015

1016 **B4. Restore Degraded Habitat**

1017 NCWRC will also identify 20 bog turtle sites that have the potential through restoration
1018 activities to provide high quality habitat to bog turtles. When those 20 have been
1019 addressed, we will assess needs at additional sites. These sites must have a bog turtle
1020 population with some suitable habitat. It is also essential that experts have determined that
1021 by taking certain steps it is likely the habitat will be increased and/or improved. We must
1022 also have the ability to manage the property, and sites owned by state or federal agencies

1023 or a conservation entity will take priority due to the ability to manage and protect the site
1024 long-term.

1025
1026 After we identify these 20 sites, NCWRC will determine the actions needed at each site and
1027 begin making a schedule and plans for implementing restoration. In some cases, projects
1028 may be small and able to be conducted with assistance from partners and/or volunteers,
1029 but in other cases, NCWRC will need to apply for additional funds, spend time designing a
1030 detailed restoration plan, and hire contractors and consult with experts to carry out the
1031 restoration project. Once these 20 sites are restored and a management schedule
1032 established to maintain them as suitable for the long-term, NCWRC will choose additional
1033 sites that also have the potential to provide high quality habitat and take action with those
1034 as well. Programs such as NRCS landowner agreements and USFWS Safe Harbor
1035 Agreements may prove to be helpful tools for habitat management, restoration, and short-
1036 term habitat protection.

1037

1038 **B5. Manipulate Populations When Beneficial**

1039 A multitude of population manipulation techniques, such as reintroductions and population
1040 augmentations, have been employed to restore wildlife populations, but very little is known
1041 about how effective they are with bog turtles. Population manipulation includes
1042 reintroductions (to sites that historically had that species), population augmentations (at
1043 sites with extant populations), introductions to sites (with no record of the species in past),
1044 and relocation of individuals from one site to another. There are many tools used as part of
1045 these efforts, including captive rearing and head-starting. We need more information about
1046 how successful these management tools are for bog turtles to determine the suitability of
1047 using them in North Carolina. In Tennessee, over 100 bog turtles were released at an
1048 experimental introduction site from 1991-2015, and although many turtles are recaptured
1049 and several nests found during surveys, there is no evidence of recruitment (no unmarked
1050 turtles captured; Dresser et al. 2017). A head-starting simulation model by Shoemaker
1051 (2011) predicted very little effect on a New York population's security even with 10 years
1052 of head-starting, although the author notes that it may be useful if survivorship of head-
1053 started individuals far exceeds that of non-head-started yearlings.

1054

1055 We need to establish objective, science-based methods for determining if and when these
1056 population manipulation techniques are appropriate, their chance of being successful, and
1057 their cost-effectiveness. This requires coming up with criteria that must be met to deem
1058 one of these methods appropriate for a specific site, as was done with a reintroduction
1059 program for Blanding's turtle (*Emydoidea blandingii*; Buhlmann et al. 2015). Given that
1060 population manipulation efforts require a large amount of time, funding, and resources, we
1061 would only want to use these methods if we felt confident that it was the best use of our
1062 resources to accomplish a specific goal for a site. If other non-population manipulation
1063 methods were available that would get us to the same or a better result with fewer
1064 resources and less of a time investment, then we would certainly choose the simpler
1065 method. We must keep in mind though that it will depend on what the underlying goal is –
1066 it could be to restore the population to viability and self-sustainability, or it could be to

1067 simply buy some time while we figure out how to address the major threats to a particular
1068 population.

1069

1070 *Population manipulation priorities:*

- 1071 - Research
- 1072 ○ Learn from studies in other states and/or start research in NC on bog turtle
 - 1073 population manipulation techniques to better understand the utility of these
 - 1074 techniques for bog turtles
 - 1075 ○ Genetic studies and guidelines on these population manipulation techniques
 - 1076 - With partners, develop an objective, science-based process for determining IF a
 - 1077 population manipulation technique is appropriate, and if so, certain criteria must be
 - 1078 met to initiate the program. This process must include a method for evaluation of
 - 1079 the program at specific times (e.g., once a year) after a population manipulation
 - 1080 project has been initiated.
 - 1081 - Complete a NCWRC policy on these types of population manipulations, perhaps as
 - 1082 an overall WRC herpetofaunal augmentation or head-starting policy. The policy will
 - 1083 include measures to limit any type of population manipulation to sites that data has
 - 1084 indicated will benefit from this action and require proof that it is appropriate and
 - 1085 likely to lead to success.
 - 1086 - With partners, develop requirements for a facility involved in handling or holding
 - 1087 turtles for population management purposes (e.g., secure from illegal collection,
 - 1088 ability to follow protocols for rearing/head-starting, disease concerns, genetic
 - 1089 concerns). Then explore options for potential facilities that could conduct any
 - 1090 rearing or head-starting in North Carolina that we could partner with on future
 - 1091 projects.
 - 1092 - Initiate a pilot-study in order to learn more about the utility of this technique with
 - 1093 bog turtles.

1094

1095 **Goal C: Further Our Knowledge about Bog Turtles**

1096 Though we have learned a lot about bog turtles in North Carolina over the last 40 years, there
1097 are areas in which we still have a need for more information. Through the use of new GIS
1098 technology, we would like to identify geographic areas to target for surveys, and eventually
1099 be able to present a more comprehensive distribution map of the species in North Carolina.
1100 Likewise, we need to continue monitoring the status and trends of the species, with a focus
1101 on creating a more organized and robust monitoring plan. Lastly, additional research is
1102 needed in order to address specific questions related to management and conservation.

1103

1104 **C1. Fill in Information Gaps about Distribution**

1105 It is likely that there are still bog turtle populations that have not been discovered in North
1106 Carolina. In recent years, through concerted efforts, NCWRC has found several bog turtle
1107 populations that we did not know existed previously. Many small wetlands are not easily
1108 accessed or seen from public roads, and given how cryptic the species is and most humans'
1109 aversion to getting deep into a muddy place; many landowners do not know they have bog
1110 turtles on their property. New GIS technology has certainly improved our ability to detect
these small mountain bogs from aerial imagery. Attempts have been made to create a

1111 predictive mapping layer in GIS (e.g., Stratmann et al. 2016), but none of these efforts have
1112 proven accurate enough to aid in narrowing down the areas to search for new populations.
1113 However, by the end of 2017, North Carolina will have LIDAR imagery for all of western
1114 North Carolina and with this GIS layer individual wetlands can be identified. Thus, NCWRC
1115 has the potential to tap into this resource and design a predictive model that will prove useful
1116 in locating bogs with high potential for bog turtles. There has been discussion about the
1117 states in the southern population collaborating to fund this type of endeavor. Not only would
1118 this predictive model be helpful in locating potential bog turtle populations, but it could also
1119 aid in finding bogs that would benefit from restoration or habitat management.

1120
1121 Another potential method that may aid in increasing our knowledge of bog turtle distribution
1122 is the use of small airplanes or drones to identify wetlands with potential for bog turtles. We
1123 could target specific areas of interest in parts of western North Carolina that are more remote
1124 with fewer roads. It may also prove helpful to reach out to private landowners through media
1125 releases, newspaper articles, and through NRCS offices, especially in counties with extant
1126 populations, to encourage them to contact the NCWRC and consider allowing us to conduct a
1127 survey of wetlands on their property.

1128
1129 It is important to learn more about the distribution of bog turtles in the state so that NCWRC
1130 has the full picture of how many populations there are, their geographic spread, and their
1131 status. With this information, we can make more informed conservation decisions.

1132
C2. Monitor Populations to Determine Status and Trends

1133 Regular monitoring through mark-recapture, site occupancy, and presence-absence
1134 surveys is important so that we can continue, or in some cases, begin to assess the status of
1135 these populations over time. Of course, monitoring is important because it can detect
1136 positive or negative changes that occur in response to our efforts or other factors. Although
1137 NCWRC and partners have monitored bog turtles for many years, the project would benefit
1138 from some big-picture planning and a more structured and scheduled monitoring plan. This
1139 will be an important first step. This plan will specify the monitoring scheme for each site.
1140 Regular monitoring and consistent mark-recapture data collection at the Tier 1 and Tier 2
1141 populations is important for assessing the status and trends of these populations over time.
1142 This information can then help inform adaptive management. We also need to gain a better
1143 understanding of detectability of bog turtles in North Carolina's varied bog habitats.

1144
1145 Monitoring will need to be multi-faceted, whereby some sites have more intensive
1146 monitoring and others are set up for simple presence-absence monitoring. At the more
1147 intensively monitored sites, we may need to do multiple survey events each year, using
1148 multiple sampling techniques (e.g., active searching, trapping, coverboards), with the
1149 cooperation of partners needed to accomplish this. Ideally, we would conduct 3 surveys a
1150 year for high priority sites. As part of this, NCWRC will take care to minimize any potential
1151 negative impact from our own work in these bogs.

1154 **C3. Conduct Research to Improve Our Understanding of Bog Turtle Ecology**

1155 Research is needed on a multitude of topics in order to better understand the ecology,
1156 habitat use, and appropriate habitat management actions to take. As we consider what
1157 needs to be done to help a site become or remain a viable population, NCWRC will likely
1158 have many questions about why these populations are currently in apparent decline. In
1159 some cases, it may be obvious why a population is in decline, but when it is not, we must
1160 use research to answer our questions and identify the main limiting factors so that our
1161 efforts can be focused on actions that will bring positive outcomes. Telemetry will likely be
1162 one of our most useful research tools. For example, telemetry can aid in determining
1163 whether female turtles are able to find adequate nesting habitat and in assessing if
1164 overwintering locations are limited or of poor quality. We may need to know if an
1165 overabundance of predators is resulting in low nest success and/or low juvenile
1166 survivorship. If a site has a very busy road adjacent to it, we may need to design a study to
1167 determine whether the road is a major threat to the population. Research studies can also
1168 be used to examine the success of certain conservation efforts. In addition to identifying
1169 major threats to survival, evaluating the success of potential conservation strategies is
1170 incredibly important (e.g., using radio-telemetry to examine the behavioral response of
1171 turtles to habitat improvements).

1172
1173 The purpose of doing research is to better understand the threats and issues for a
1174 particular population so that we can choose the most effective tools from the conservation
1175 toolbox. If we already know what actions to take, then research is not necessary. NCWRC
1176 will only pursue research when the results will aid in our conservation and management
1177 decisions. Given the importance of these Tier 1 and 2 sites, we must carefully weigh the
1178 needs and benefits of the information gained against any risks from the work and take
1179 great care to minimize any potential negative impact to these populations during research.

1180
1181 Some of the top priority research topics we need to address are listed below, but this list is
1182 certainly not exhaustive. As we learn more and as we begin working towards the goals in
1183 this Plan, different questions may arise that need to be answered.

- 1184
1185 1) Research life stages that affect potential for successful recruitment into adults (adult
1186 fertility, adult female fecundity, proportion of females that produce fertile eggs each
1187 year, egg survival/nest success, hatchling survival, juvenile survival). Learn more about
1188 which of these stages is the limiting factor(s) so we can better target our efforts.
1189 2) Gain a better understanding of which threats (e.g., predation, flooding, poor nesting
1190 habitat, infertility) are playing the most significant role(s), and which management
1191 actions may be most effective and economical to address these issues (e.g., predator
1192 control, nest protection, habitat management, population augmentation)
1193 3) Identify new wetlands with turtle populations (e.g., LIDAR proposal)
1194 4) Investigate suitability of population manipulation (e.g., reintroduction, population
1195 augmentation, captive breeding)
1196 5) Examine the efficacy of different vegetation management techniques (e.g., appropriate
1197 level and use of grazing at different sites). Includes grazing studies focused on ideal
1198 density/grazers, influence of detectability on perception of population status,
1199 importance of grazers breaking up wetland soil.

- 1200 6) Develop predictive population modeling program specific to bog turtles that can be
1201 used to determine which conservation and management actions (e.g., nest protection,
1202 habitat restoration, head-starting) are most feasible, cost-effective, and provide the
1203 most benefit to each individual population.
- 1204 7) Conduct genetic studies to determine gene flow and population health and to guide
1205 population management actions such as reintroductions, augmentations, relocations,
1206 and captive-breeding.
- 1207 8) Improve understanding of landscape ecology and metapopulation dynamics
- 1208 9) Improve understanding of bog hydrology and water quality
- 1209 10) Examine differences in food availability across bogs
- 1210 11) Conduct in-depth studies to improve our understanding of dispersal-distances traveled,
1211 habitat used
- 1212 12) Investigate the effects of climate change on bogs (e.g., hydrology, vegetation, resiliency
1213 of bogs over long-term)
- 1214 13) Conduct behavioral study of reproduction; parentage study (e.g., are there behavioral
1215 limitations that can affect reproduction at some sites—can adults find each other, do
1216 they breed with close relatives and if so, are those offspring viable?)
- 1217 14) Understand more about overwintering sites—is this a limitation at some sites?
- 1218 15) Refine our survey methods so we can better detect hatchlings and juveniles
- 1219 16) Identify diseases and health issues that may affect certain populations
- 1220 17) Occupancy modeling to determine what qualifies as suitable habitat, adequate habitat
1221 size, and adequate habitat quality.

1224 **Goal D: Expand Outreach Efforts**

1225 Although we have a strong network of collaborators and solid relationships with many
1226 private landowners, there is still room for improvement. Bringing additional partners to
1227 the table could make a significant difference in conservation of the species if it brings
1228 increased funding, programs, and protection of the species. Likewise, having a more robust
1229 outreach program for landowners would help us to effect more positive change and reach
1230 more landowners.

1232 **D1. Involve More Collaborators**

1233 We need to continue building our relationships with entities that can provide management
1234 and protection assistance to landowners, including NRCS and land trusts. The main
1235 objective is to improve our communication and collaboration with NRCS staff about bog
1236 turtle conservation needs and how they can help. Another task will be to provide
1237 educational programs for NRCS staff about mountain bogs and bog turtles. With land trusts,
1238 we need to provide information that outlines specifically how and where we need their
1239 assistance with protection measures for bogs. NCWRC will continue to build on the strong
1240 relationships we already have with many land trusts in the region and take steps to
1241 strengthen those that have not been as active in bog turtle conservation efforts.

1242 A second effort will be to take several steps towards improving our collaboration with law
1243 enforcement officers. A first step is to provide educational forums for law enforcement

1245 officers so that they can aid in education and protection of the species and its habitat in the
1246 state. NCWRC will focus our efforts on western North Carolina and topics would include
1247 bog turtle ecology, habitat, and what to look for with potential illegal collection of the
1248 species. We would also aim to strengthen our relationships and work more closely with law
1249 enforcement officers that have bog turtle populations in their districts so that they will
1250 know the geographic areas that need extra patrolling for potential poachers.

1251

1252 **D2. More Effectively Reach Landowners**

1253 In collaboration with partners, develop and implement an effective outreach and education
1254 program about bog turtles that is designed for landowners that have bog turtles and/or
1255 mountain bogs on their property. A first step is to form a planning committee to determine
1256 what the most effective products and/or programs will be. This could include an
1257 information packet, an educational program we design, and/or any other idea the group
1258 comes up with. Project Bog Turtle and the USFWS each have some materials that may be
1259 useful, but they likely need to be updated. The committee will decide whether this is a
1260 single effort or if the committee will meet on a regular basis to continue working on
1261 education and outreach for landowners.

1262

1263

1264 **SUMMARY OF ACTIONS NEEDED**

1265 NCWRC has summarized the detailed description of conservation actions needed into Table
1266 1, in general order of priority. However, note that each of these actions are high priority and
1267 necessary. Additional actions may be identified as we learn more about this species and the
1268 sites in North Carolina. Actions will be undertaken as time and resources allow.

1269

1270 **TABLE 1. A SUMMARY OF CONSERVATION ACTIONS NEEDED TO ADDRESS THE GOALS, THE PARTNERS
1271 INVOLVED, AND THE DESIRED OUTCOMES OF EACH ACTION. THESE ACTIONS ARE LISTED GENERALLY IN
1272 ORDER OF PRIORITY, THOUGH ALL ACTIONS ARE CONSIDERED IMPORTANT AND NECESSARY.**

#	ACTIONS	GOALS	PARTNERS	DESIRED OUTCOMES
1	Rank all known populations from most to least viable, with the top 10 populations called Tier 1 and the 10 next best populations "Tier 2". Focus on Tier 1 initially until determined "viable" then Tier 2, then continue to next 10 best populations.	B	USFWS, PBT, NCNHP, NPS-BRP, State Parks	1) Organized plan for focusing efforts, 2) Many viable bog turtle populations in NC.
2	For Tier 1 (Tier 2 sites when possible) assess threats, determine highest priority actions, and act to address identified threats (e.g., vegetative succession, vehicles, disease, predation) and other needs (e.g., research, land protection, monitoring).	A, B, C	USFWS, NRCS, and PBT, plus agencies and owners of sites identified.	1) Reduction of threats affecting Tier 1 and Tier 2 sites, 2) Securing Tier 1 and Tier 2 populations as solidly viable.

#	ACTIONS	GOALS	PARTNERS	DESIRED OUTCOMES
3	Take actions that are needed to help keep the Tier 2 populations from being extirpated or undergoing extreme declines	B	USFWS, PBT, and landowners	Maintenance of Tier 2 populations as still recoverable.
4	Evaluate Tier 1 and Tier 2 sites to determine if habitat management is needed and carry out any needed management.	A, B	USFWS, BLN, PBT, NCNHP, NPS-BRP, State Parks, NRCS etc.	All Tier 1 and Tier 2 sites are managed well over long term.
5	Develop a prioritized list of sites that need protection. In the short-term, identify and protect 20 bog turtle populations that can be protected.	B	PBT, NCNHP, USFWS, other partners	1) Prioritized list of sites that have no protection that have known populations, 2) Protect 20 bog turtle populations.
6	Protect Tier 1 sites and secondarily, the Tier 2 sites	B	Land trusts, State Parks, NCNHP, TNC, and USFWS	Protect all Tier 1 and Tier 2 sites and their watersheds.
7	Protect bogs that have willing landowners (fee-simple, donation, conservation easement, etc.), with the long-term goal of protecting all known bog turtle populations.	B	Land trusts, State Parks, NCNHP, TNC, and USFWS	Protect all known bog turtle populations.
8	Identify 20 sites that have potential through management/restoration to provide high quality habitat. Then determine actions needed at each of these 20 sites, make a schedule, and implement management/restoration.	B	PBT, USFWS, owners of sites, other partners	1) List of 20 sites will target that have potential to provide high quality habitat, 2) Regular habitat management and restoration of these 20 sites.
9	Create a prioritized schedule for habitat management that includes all extant populations, including the specific needs of each site.	B	PBT, USFWS, and other partners	Organized schedule of habitat management for all known sites with extant populations.
10	Research life stages that affect potential for successful recruitment into adults. Learn more about which stages are limiting so can better target efforts.	C	Researchers	Data gaps filled through research about life stages that affect recruitment (e.g., hatchling success, hatchling and juvenile survival).
11	Learn more about role of different threats and which management actions may be most effective and economical to address these threats	A	Researchers, and other partners	1) Solid understanding of relative roles of various threats to bog turtles, 2) solid understanding of the effectiveness of different conservation actions to address these threats.

#	ACTIONS	GOALS	PARTNERS	DESIRED OUTCOMES
12	Develop a population viability modeling program to aid in assessing utility of various conservation and management actions for their benefit to a population.	C	Researchers	Tool to improve our planning and management abilities for bog turtles in NC.
13	Build relationships with entities that provide management and protection assistance to landowners (e.g., NRCS, land trusts) through improved communication and collaboration and educational programs.	D	USFWS, NCRS, land trusts	1) Knowledge of bog turtle conservation needs and engagement from NRCS, land trusts, and other entities that provide management and protection assistance to landowners, 2) Many landowners signed up for programs that help conserve and/or protect bog turtles.
14	Generate a ranked list of metapopulations from most to least intact functioning. Initially focus on top 5. Make concerted effort to protect, appropriately manage, and when necessary, restore these 5 metapopulations as well as the land between them and within their watersheds.	B	USFWS, PBT, other partners	1) Organized plan for protecting, managing, and restoring metapopulations, their watersheds, and the land/water between, 2) Full protection, appropriate management, and necessary restoration accomplished within these 5 best metapopulations in the state.
15	Determine most appropriate monitoring scheme for Tier 1 and Tier 2 sites and implement.	C	PBT, USFWS, other partners	Solid monitoring plan for all populations at Tier 1 & Tier 2 sites being carried out in organized, regular, and consistent basis.
16	Do big-picture planning and develop a structured and scheduled monitoring plan that includes all known bog turtle sites. Then implement this monitoring plan.	C	PBT	Solid monitoring plan for all known bog turtle populations being carried out in organized, consistent, and regular basis.
17	Conduct research to answer critical questions about bog turtle biology, habitat requirements, population health, genetics, and habitat management, etc.,	C	Researchers and other partners	Gain relatively good understanding of major threats, habitat requirements, turtle population dynamics, and landscape ecology; use knowledge to appropriately manage habitat and turtle populations.

#	ACTIONS	GOALS	PARTNERS	DESIRED OUTCOMES
18	Take steps to improve collaboration with law enforcement officers (e.g., educational forums, strengthen relationships)	D	USFWS, other partners	Law enforcement officers that work within NC, especially those within the geographic range of the species, are very knowledgeable about the species, the signs of illegal collection, the sites within their work area, and are acting to search for illegal collection and other illegal activity related to bog turtles.
19	Develop a decision framework (objective, science-based) for determining if and when population manipulation techniques are appropriate, their chance of being successful, and their cost-effectiveness.	B	PBT, USFWS, other partners	Clear and effective decision framework based on science that can be used to determine if and when population manipulation techniques are appropriate at a site.
20	Make a concerted effort to reach out to landowners, educate, build relationships, and connect land-conservation partners (e.g., land trusts) to landowners.	D	PBT, USFWS, other partners	These efforts and good relationships lead to more bogs protected and managed appropriately, and more bog turtle populations discovered.
21	Write management plans for bog turtle sites, prioritizing sites with complex and immediate management needs, a population that would benefit, and that NCWRC has permission to manage. Then apply these plans.	B	PBT, USFWS, owners of sites	1) Management plans are helpful documents in guiding our actions and help us focus our efforts where needed most, 2) Sites with management plans are managed appropriately.
22	Develop a predictive model using LIDAR (and/or other promising methods) to identify new potential wetlands and increase our knowledge of the distribution of bog turtles in NC.	C	Other states, researchers	1) This model is a tool with great utility in helping us locate previously unknown bog turtle populations, 2) We fill in the distribution gaps on for the species in NC.
23	Through collaboration with partners, including PBT, land trusts, TNC, and USFWS, develop and implement an effective outreach and education program for landowners	D	PBT, land trusts, TNC, USFWS	1) Better educated landowners, 2) More resources we can use to reach, educate, and influence about bog turtles, their ecology and habitat, and the importance of protecting and managing their habitat, 3) More habitat protected and managed appropriately.

#	ACTIONS	GOALS	PARTNERS	DESIRED OUTCOMES
24	Develop requirements and guidelines for captive turtle facilities and consider options for facilities to partner with	B	PBT, USFWS	These guidelines will provide protocols for captive facilities.
25	Formulate a multi-faceted plan to fill in data gaps on bog turtle distribution.	C	PBT, USFWS	A plan will provide a clear path forward for increasing our knowledge of the species' distribution in NC.
26	Address priority research questions (in the list), identify additional data needs, and act to set up studies to answer those questions.	C	PBT, USFWS, other partners	Answering research questions will help advance bog turtle conservation efforts.

1273

1274 **ECONOMIC IMPACTS**

1275 The economic costs associated with each conservation goal are estimates dependent on
 1276 many factors. Although NCWRC has attempted to break each estimate down to an average
 1277 per-site cost, each site will require a unique set of actions and sites vary in size. Thus, the
 1278 actual cost for performing on-the-ground actions will vary among sites as will the average
 1279 cost per-site listed below.

1280 **Potentially Affected Parties**

1281 This Plan discusses topics and proposes initiatives that could generate both costs and
 1282 benefits to a wide variety of individuals and organizations. The following table provides
 1283 some detail about the potentially affected parties (Table 2).

1284

1285

1286

TABLE 2. A LIST OF POTENTIALLY AFFECTED PARTIES BY THIS PLAN, INCLUDING COSTS AND BENEFITS

Type	Local	State	National
Governments	<ul style="list-style-type: none"> - Cities - Counties 	<ul style="list-style-type: none"> - WRC - DOT - DEQ - Universities (Public) - DCR (State Parks, NHP) - NWAC - NC Plant Conservation Program - Division of Soil and Water Conservation - Zoos and Nature Centers (Public) 	<ul style="list-style-type: none"> - USFWS - USDA (Pisgah & Nantahala NF) - NRCS - NPS (Blue Ridge Parkway) - USDA (APHIS) - EPA (wetland regulation) - U.S. Army Corp of Engineers (permits to alter wetlands)

Type	Local	State	National
Businesses	<ul style="list-style-type: none"> - Wildlife Damage Control Agents - Landscaping companies - Animal grazing companies - Restoration firms - Engineering firms - Farms (esp. cattle farms) - Reptile rehabilitators 	<ul style="list-style-type: none"> - Universities (Private) - Zoos and Nature Centers (Private) 	<ul style="list-style-type: none"> - Universities (Private) - Zoos and Nature Centers (Private)
Groups	<ul style="list-style-type: none"> - Riverlink - MountainTrue - Riverkeepers - Mainspring Conservation Trust - Conserving Carolina - Blue Ridge Conservancy - Piedmont Land Conservancy - Highlands-Cashiers Land Trust - Southern Appalachian Highlands Conservancy - Foothills Conservancy - Catawba Lands Conservancy 	<ul style="list-style-type: none"> - NC Herpetological Society - NC PARC - The Nature Conservancy - Clean Water Management Trust Fund - Project Bog Turtle - Conservation Trust for North Carolina 	<ul style="list-style-type: none"> - PARC and SEPARC - SSAR - Bog Learning Network - Turtle Survival Alliance - Turtle Conservation Fund
Individuals	<ul style="list-style-type: none"> - Landowners - Private donors - Public in regions with bog turtles 		

1287

1288 Costs to NCWRC

1289 The implementation of the actions listed in the Conservation Actions section will require
 1290 upfront and long-term costs for NCWRC. The amounts given here are estimates and are
 1291 certain to change over time. Some work on Goals A, B, C, and D will be completed with
 1292 existing staff and resources, and therefore will not add additional costs.

1293

1294 In many cases, using existing agency staff to perform new or additional tasks comprise
 1295 opportunity costs (i.e., an existing or different task will be forgone). All efforts will require
 1296 additional staff time in planning and coordination; permanent staff time is assessed at
 1297 \$34.00 per hour. Costs to produce the NC Bog Turtle Conservation Plan were incurred by
 1298 NCWRC staff writing and reviewing the document. The total estimated cost is \$7,500.

1299

1300 **Costs to NCWRC by Goal**

1301 ***Goal A: Identify threats to bog turtle populations***

1302 Most of the work on this goal can be accomplished with current NCWRC staffing and
1303 through assistance from collaborators. However, in some instances research may be
1304 necessary to complete a site-specific threat assessment and in that case, costs may arise,
1305 but that is accounted for within Goal C (below).

1306 ***Goal B: Maintain and maximize the number of viable populations***

1307 Measures to address threats to bog turtle populations include materials for nest protection
1308 (e.g., predator excluders, wildlife cameras) and predator removal services, among others.
1309 Habitat management actions include equipment expenses (e.g., chainsaws, brushcutters,
1310 chipper rental), supplies (e.g., herbicide, gloves, safety gear), and paying for services (e.g.,
1311 manual labor, goat rental). The costs for the total management and threat assessment
1312 measures are estimated to range between \$200 - \$2500 per site. Some expenses will be
1313 one-time costs while others will occur annually (e.g., vegetation and predator management)
1314 at an estimated cost of \$200 per acre per year.

1315

1316 In addition to existing staff time for coordination, NCWRC will also need to provide funds
1317 for fee-simple purchases of bog properties. The per-acre cost of land varies widely
1318 throughout the bog turtle range in North Carolina, therefore the price for land acquisitions
1319 are difficult to assess. Acquired parcels can range in price but average \$7,500 per acre and
1320 are typically about 150 acres for a bog and its immediate watershed. Furthermore, as
1321 desirable parcels become available, they should be evaluated and purchased through
1322 NCWRC's customary land acquisition process. Once we have identified the Tier 1 and Tier 2
1323 populations and the 5 best metapopulations, we can estimate the cost of protecting them.

1324

1325 The steps to restore habitat will be different for each site, although restoration will likely be
1326 needed to some degree at most sites. Some sites with severely degraded hydrology will
1327 require intense and costly efforts. Estimates of habitat restoration are \$10,000 - \$200,000
1328 per site.

1329

1330 ***Goal C: Further our knowledge about bog turtles***

1331 This conservation work will require at least one 11-month seasonal technician position to
1332 focus on goals B and C. This technician will take the lead in developing a prioritized
1333 schedule for bog habitat management, coordinate habitat management activities at bogs,
1334 and assist in writing bog management plans, and other related tasks. The technician will
1335 also assist in ensuring that bog turtle sites are adequately monitored, including
1336 coordination of volunteers and partners to assist with these surveys. The current cost for a
1337 seasonal technician is \$20.00 per hour; the duties of the technician require about 2,000
1338 hours per year.

1339

1340 NCWRC will pursue setting up a contract with a researcher for a LIDAR-based Species
1341 Distribution Model. For a master's level research project, the estimated cost of this is
1342 \$250,000.

1343

1344 NCWRC has identified a few major questions that will increase our knowledge of bog turtle
1345 biology and thus our ability to plan and execute meaningful projects to appropriately
1346 conserve bog turtles. The research projects outlined for Goal C will range in cost from
1347 \$50,000 - \$500,000 depending on if and how research questions get grouped into a project
1348 package by one entity (which could potentially reduce costs).
1349

1350 ***Goal D: Expand outreach efforts***

1351 NCWRC will assist in creating updated outreach materials. Also, staff from the Wildlife
1352 Education Division will likely need to assist in some of the outreach and education activities
1353 involved in Goal D. Costs are estimated at \$2,000.
1354
1355

1356 **Costs to Others**

1357 **Private**

1358 If private landowners are interested in providing funds for bog habitat management, they
1359 can do so, but otherwise all costs will be covered by NCWRC, other partners, and
1360 conservation grants. All activities on private land will be completely voluntary and
1361 landowners will incur no expenses unwillingly.

1362 **Business/Commercial**

1363 Businesses will benefit through opportunities to sell equipment and supplies and provide
1364 services (grazing rental company, hardware stores, equipment rental companies).
1365

1366 **Municipal**

1367 Nature Centers and other education-based programs could incur costs if they are interested
1368 in developing education and outreach programs.
1369

1370 **Other State Agencies**

1371 There is the potential for costs to NC Department of Transportation for mitigation and
1372 measures to address road mortality adjacent to bog turtle sites. This could include
1373 installation of underpasses, fences to keep turtles away from road, or other measures to
1374 reduce mortality.
1375

1376 Any of the state agencies that have bog turtle populations on their property may incur costs
1377 for labor, supplies, and equipment for habitat management. This includes State Parks and
1378 possibly State Forests. Potential costs could involve costs for fee-simple purchase of
1379 properties for conservation protection.

1380
1381 The NC Zoological Park could incur costs if they add additional education and outreach
1382 materials and/or programs on bog turtles.
1383

1384 The NC Department of Environmental Quality could need to review more permits for
1385 wetland restoration projects, but this will likely fit within their current staffing capacity.
1386

1387 **Federal Agencies**

1388 The USFWS will incur costs by helping fund protection efforts (fee simple, easements),
1389 providing staff for coordination and collaboration, providing funds for development of
1390 outreach and education information, and for printing of materials for coordination
1391 meetings. They will also assist with monitoring of bog turtle populations, but this will likely
1392 be within their current staffing capacity.

1393

1394 NRCS will incur costs through their landowner-wildlife programs. Their staff will need
1395 additional training as they get more involved in bog turtle work, but that will be provided
1396 by current NCWRC and USFWS staff.

1397

1398 Several federal agencies, including the Blue Ridge Parkway and the USDA's Pisgah and
1399 Nantahala National Forests, may incur costs for labor, supplies, and equipment for habitat
1400 management on their property, as well as costs for addressing other threats to bog turtles
1401 on their property (e.g., poaching, nest protection). Potentially this could also involve costs
1402 for fee-simple purchase of properties for conservation protection.

1403

1404 The US Army Corps of Engineers may also be more involved with permit review as we
1405 launch additional wetland restoration projects, but this will likely fit within their current
1406 staffing capacity.

1407

1408 **NGOs**

1409 Land trusts and The Nature Conservancy may incur costs for labor, supplies, and
1410 equipment for habitat management on their property or others, as well as costs for
1411 addressing other threats to bog turtles on their property (e.g., poaching, nest protection).
1412 Given the mission of these organizations, it is likely that they will also have costs for
1413 conservation easements and fee-simple purchase of properties for conservation protection.

1414

1415 **Efforts to Minimize Costs and Adverse Economic Impacts**

1416 NCWRC's work to achieve the goals presented in this Conservation Plan will be reduced by
1417 the many partners interested in bog turtle conservation. Costs for research will also be
1418 reduced by universities and other research partners providing matching funds. Proactive
1419 conservation before federal listing will greatly reduce management costs as compared to
1420 the costs under Endangered Species Act protection. It benefits both public and private
1421 landowners to conserve bog turtles before listing.

1422

1423 **Economic Benefits**

- 1424 • NRCS programs, such as Working Lands for Wildlife, provides benefits to
1425 landowners that have bog turtles on their property. These programs can provide
1426 money to willing landowners, potentially reduce their tax burden, and provide funds
1427 to do projects on their land. State Wildlife Grants may also provide benefits to
1428 interested landowners in that their wetlands may be managed at no cost to them.
- 1429 • Landowners can have their tax burden reduced if they sign up for NCWRC's Wildlife
1430 Conservation Land Program (WCLP).

- The work involved in the Plan will result in support of local businesses, agencies, and universities through sales of equipment and supplies, as well as payment for services and consulting. This includes payment for vegetation management, predator removal at bog turtle sites (e.g., Wildlife Damage Control Agents, APHIS), and services provided by landscaping companies, engineering firms, wetland restoration companies, university researchers, among others.
- Land trusts and The Nature Conservancy benefit from grants to help fund their mission
- Funding from grants could also benefit local businesses and universities.

GLOSSARY

Captive breeding: The process of breeding animals in controlled environments by experts within well-defined settings, such as wildlife reserves, zoos and other commercial and noncommercial conservation facilities.

Conservation easement: A conservation easement is a restriction placed on a piece of property to protect its associated resources. The easement is either voluntarily donated or sold by the landowner and constitutes a legally binding agreement that limits certain types of uses or prevents development from taking place on the land in perpetuity while the land remains in private hands.

Extirpation: Local extinction or extirpation is the condition of a species (or other taxon) that ceases to exist in the chosen geographic area of study, though it still exists elsewhere. Local extinctions are contrasted with global extinctions.

Fecundity: The actual reproductive rate of an organism or population, measured by the number of gametes (eggs), seed set, or asexual propagules.

Fee-simple purchase: A fee simple purchase transfers full ownership of the property, including the underlying title, to another party.

Fertility: The quality of an organism's ability to produce offspring, which is dependent on age, health, and other factors.

GIS: A geographic information system (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data.

Head-starting: The act of rearing wild hatchlings in protective enclosures before release at less susceptible size/age, thereby avoiding the heavy mortality of young age classes in the wild.

High-quality habitat: This habitat has the components of "suitable habitat," plus the following characteristics: 1) areas with deep, loose low strength soils (Feaga et al. 2013), 2) presence of sphagnum mosses, rushes, sedges, and some wetland shrub species, 3) mosaic of low and shrubby vegetation with 1 or more relatively large areas with very low vegetation (ideally sphagnum, but also rushes and sedges) that receive full sun, 4) relatively unaltered hydrology with stable ground-water levels that are $8\text{ cm} \pm 1\text{ cm}$ ($3.1\text{ in} \pm 0.4\text{ in}$) average depth from surface over multiple years, without flooding and inundation (Feaga 2010), 5) presence of subsurface root structures and/or tunnels, 6) adequate vegetation to conceal turtles when basking

1473 on surface, 7) minimal threats within habitat and/or adjacent to property (e.g., busy
1474 roads, over-abundance of predators).

1475 Hydrology: A science dealing with the properties, distribution, and circulation of water on
1476 and below the earth's surface and in the atmosphere

1477 Invasive species: Is a species that is 1) non-native (or alien) to the ecosystem under
1478 consideration and 2) whose introduction causes or is likely to cause economic or
1479 environmental harm or harm to human health.

1480 LiDAR: This term stands for Light Detection and Ranging and is a remote sensing method
1481 that uses light in the form of a pulsed laser to measure ranges (variable distances) to
1482 the Earth.

1483 Metapopulation: Consists of a group of spatially separated populations of the same species
1484 which interact at some level.

1485 Mycoplasma: Any of numerous parasitic microorganisms of the class Mollicutes,
1486 comprising the smallest self-reproducing prokaryotes, lacking a true cell wall and
1487 able to survive without oxygen.

1488 Occurrence record: A location with a record of a bog turtle is an occurrence.

1489 Population: A group of bog turtles that interact and share the same habitat

1490 Population augmentation: The addition of animals to an existing population, usually a small
1491 population that has habitat that can support a larger population that has not been
1492 expanding on its own due to impacts from threats, stochastic events, or
1493 demographic limitations. Animals can be translocated from a source population or
1494 may be added through captive breeding or head-starting of individuals that
1495 originated at the site.

1496 Population manipulation: Refers to reintroductions, population augmentations, relocation,
1497 head-starting, and captive rearing.

1498 Ranavirus: Ranavirus is a genus of viruses, in the family Iridoviridae, that includes viruses
1499 that are infectious to amphibians and reptiles.

1500 Recruitment: Occurs when juvenile organisms survive to be added to a population, by birth
1501 or immigration, usually a stage whereby the organisms are settled and able to be
1502 detected by an observer.

1503 Restoration: An intentional activity that initiates or accelerates the recovery of an
1504 ecosystem with respect to its health, integrity and sustainability.

1505 Southern Appalachian Bog: Includes open, acidic, permanently saturated wetlands of flat
1506 stream bottoms or gentle slopes, with a distinctive bog flora, with varying amounts
1507 of shrubs and sometimes with moderate amounts of tree cover, but with a well-
1508 developed, dense herbaceous layer and, generally, extensive Sphagnum cover. These
1509 wetlands generally appear to have a substantial amount of ground water input, and
1510 therefore would be considered poor fens.

1511 Suitable habitat: Habitat composed of the following at a minimum: 1) soft, saturated soils,
1512 2) spring-fed hydrology, and 3) an area with low vegetation (no canopy) that gets
1513 full sun.

1514 Threatened due to Similarity of Appearance: A species that is threatened due to similarity
1515 of appearance with another listed species or the same species in another geographic
1516 area and is listed for its protection. Species listed as T(S/A) are not biologically
1517 endangered or threatened and are not subject to Section 7 consultation with USFWS.

1518 Watershed: A drainage basin or 'catchment area' is any area of land where precipitation
1519 collects and drains off into a common outlet, such as into a river, bay, or other body
1520 of water.

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