FINDING OPPORTUNITIES FOR PRE-COMPLIANCE SPECIES CONSERVATION IN NORTH CAROLINA

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LIST OF ABBREVIATIONS

BHQ	"Baseline Habitat Quality" assurance
BMP	Best management practices
CADOT	California Department of Transportation
CBD	Center for Biological Diversity
CWA	Clean Water Act
DOI	Department of the Interior
EDF	Environmental Defense Fund
EO	Element occurrence
EPA	Environmental Protection Agency
ESA	Endangered Species Act
FICMNEW	Federal Interagency Committee for Management of Noxious and Exotic Weeds
FWS	U.S. Fish and Wildlife Service
HCP	Habitat Conservation Plan
IUCN	International Union for the Conservation of Nature
km	Kilometer
MRLC	Multi-Resolution Land Characteristics Consortium
NAR	"No Additional Restrictions" assurance
NCCGIA	North Carolina Center for Geographic Information and Analysis
NCDENR	North Carolina Department of Environment and Natural Resources.
NCTA	North Carolina Turnpike Authority
NCWRC	North Carolina Wildlife Resources Commission
NEPA	National Environmental Policy Act
NHD	National Hydrography Dataset
NHP	Natural Heritage Program
NPS	Non-point source runoff
NRCS	Natural Resources Conservation Service
rkm	River kilometer
SCDNR	South Carolina Department of Natural Resources
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geologic Survey
WWF	World Wildlife Fund

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EXECUTIVE SUMMARY

POLICY QUESTION

Which pre-compliance conservation strategies have the greatest potential to conserve multiple unprotected species in North Carolina?

BACKGROUND

Pre-compliance conservation involves landowners working cooperatively with conservation managers to conserve imperiled yet unprotected species. The Environmental Defense Fund (EDF) wants to pursue pre-compliance measures in North Carolina. Unfortunately, species require different mitigation strategies on the basis of the threats they faced and their ecological characteristics. EDF is unclear which strategies could potentially conserve the greatest number of species.

This project analyzes different conservation strategies on their ability to protect multiple species simultaneously in several geographic regions of North Carolina. It hopes to provide a tool to aid EDF in its ability to optimize preemptive species conservation.

RECOMMENDED CONSERVATION STRATEGIES

EDF should consider the following criteria when deciding between pre-compliance strategies in each region:

- Address the primary threats or stressors facing populations in the region
- Align with the ecological characteristics of the species in the region
- Align with the incentives, motivations, and opportunities of the region's landowners

Accounting for these criteria, I recommend that EDF implement the following strategies:

1) In the high-elevation western region of North Carolina, landowners should retrofit dams to naturalize stream flow conditions and allow for the passage of migratory species. The incentives for pre-compliance action may differ for private and public landowners. Private landowner participation might be incentivized by conservation easements or through protections from future regulatory action. Public landowners might be motivated by federal guidance promoting ecosystem services. I recommend focusing on this region first, due to its large number of unique species and potential for federal cooperation.
2) In the southeastern region of North Carolina, landowners should establish riparian buffers to limit siltation and runoff, reduce stream temperatures, and restore woody debris to aquatic ecosystems. Landowner participation might be incentivized by direct payments or through protections from future regulatory action. I recommend focusing on this region second, due to its large number of unique species.
3) In the agricultural eastern region of North Carolina, landowners should establish riparian buffers and improve irrigation technology; these strategies could be incentivized by direct payments or through protections from future regulatory action. Landowners should also adopt best management practices regarding fertilizer application, water use, and livestock management; these practices could be incentivized by conservation easements or the option to revert to previous

management practices in the future. Reverse auctions could be used to identify participating landowners for all mitigation strategies in this region. I recommend focusing on this region third due to the abundant opportunities for landowner compensation provided by farm bill conservation programs.

4) In the developed central region of North Carolina, landowners should employ a combination of mitigation strategies. Potential strategies include riparian buffering, adopting best management practices, modifying development, retrofitting dams, stream shading, controlling erosion, removing invasive species, and conducting on-site stream restoration. I recommend prioritizing this region fourth; its large variety of threats might make it difficult to develop a comprehensive conservation plan.

METHODS

1. After identifying species that fit my criteria (wetland or aquatic animals in North Carolina that are imperiled yet unprotected), I grouped species populations into four geographic regions on the basis of spatial proximity, dominant land uses, and elevation. This was done to identify regions where a mitigation strategy might cover multiple species threatened by similar stressors.
2. I next conducted a spatial analysis of five stressors threatening target species populations: agriculture, development, deforestation, roads, and dams. For most stressors, threat levels were determined by the density of the threat within a 5 km radius; for dams, threat level was determined by the distance from the nearest upstream dam.
3. I conducted a literature review to identify common mitigation techniques for each threat class.
4. I analyzed programs that are commonly used to reach conservation agreements with landowners to identify policy alternatives, or tools. I then analyzed how the policy tools align with the previously identified mitigation techniques; this produced a list of mitigation techniques and policy tools that could be employed within each geographic region.
5. I then conducted a literature review on the ecological characteristics of the target species to ensure that the chosen mitigation techniques and policy tools aligned with the dominant species traits in each region.

DISCUSSION

This project identified several opportunities for effective pre-compliance species conservation in North Carolina. While it tried to identify a "best option" for each geographic region, there are often multiple strategies with the potential for effective conservation.

There are many resources that landowners and conservation managers can use to implement pre-compliance agreements. Section 319 of the Clean Water Act provides resources that allow farmers to reduce their NPS runoff (CWA 33 U.S.C. § 1329, EPA 2005). A variety of farm bill conservation programs provide technical assistance, financial compensation, and education to help farmers reduce their environmental impacts.

This tool can potentially help EDF conserve many species by bypassing a long and contentious listing process under the federal Endangered Species Act.

CHAPTER 1: INTRODUCTION

Pre-compliance conservation involves private landowners working cooperatively with conservation managers to conserve imperiled yet unprotected species. This strategy has the potential to conserve many species by bypassing a long and contentious listing process under the federal Endangered Species Act (ESA). The Environmental Defense Fund (EDF) wants to pursue pre-compliance measures in North Carolina. Unfortunately, species require different mitigation strategies on the basis of the stressors faced and their unique suites of life history traits. EDF is limited in its ability to design an individual strategy for each species. This project identifies regional pre-compliance programs that simultaneously protect multiple species on the basis of spatial proximity, shared stressors, and similar life history traits. This tool hopes to aid EDF in its ability to optimize species conservation.

In a 2011 settlement between the Center for Biological Diversity (CBD) and the U.S. Fish and Wildlife Service (FWS), FWS agreed to make listing decisions on more than 700 candidate species over the next 10 years (CBD 2011). This listing process will likely be contentious and costly to all stakeholders, and it will be beneficial for cooperative conservation measures to begin prior to a listing decision. Even if an ESA listing cannot be avoided, pre-compliance efforts can effectively establish management strategies that incorporate both species needs and landowner interests.

The 2011 settlement includes 82 plant and animal species that occur within North Carolina. This project focuses on 30 aquatic or wetland animal species for which spatial element occurrence data could be obtained (Table 1). These target species represent a broad diversity of taxonomic groups, including: ten species of freshwater mussel; six species of crayfish; five species of fish; three species of dragonfly; three species of salamander; one butterfly species; one snail species; and one stonefly species.

TABLE 1: Target Species

Latin Name	Common Name	Taxa
Alasmidonta varicosa	Brook Floater	Mussel
Cambarus catagius	Greensboro Burrowing Crayfish	Crayfish
Cambarus chaugaensis	Chauga Crayfish	Crayfish
Cambarus georgiae	Little Tennessee Crayfish	Crayfish
Cambarus parrishi	Hiwassee Headwater Crayfish	Crayfish
Cambarus spicatus	Broad River Spiney Crayfish	Crayfish
Cryptobranchus alleganiensis	Hellbender	Salamander
Desmognathus aeneus	Seepage Salamander	Salamander
Elassoma boehlkei	Carolina Pygmy Sunfish	Fish
Elliptio lanceolata	Yellow Lance	Mussel
Fusconaia masoni	Atlantic Pigtoe	Mussel
Fusconaia subrotunda	Longsolid	Mussel
Gomphus septima	Septima's Clubtail	Dragonfly
Lampsilis fullerkati	Waccamaw Fatmucket	Mussel
Lasmigona holstonia	Tennessee Heelsplitter	Mussel
Lasmigona subviridis	Green Floater	Mussel
Macromia margarita	Mountain River Cruiser	Dragonfly
Megaleuctra williamsae	Smokies Needlefly	Stonefly
Moxostoma robustum	Robust Redhorse	Fish
Moxostoma sp. 2	Sicklefin Redhorse	Fish
Necturus lewisi	Neuse River Waterdog	Salamander
Noturus furiosus	Carolina Madtom	Fish
Noturus gilberti	Orangefin Madtom	Fish
Ophiogomphus edmundo	Edmund's Snaketail	Dragonfly
Orconectes virginiensis	Chowanoke Crayfish	Crayfish
Planorbella magnifica	Magnificent Rams-Horn	Snail
Pleurobema oviforme	Tennessee Clubshell	Mussel
Pleuronaia gibberum	Tennessee Pigtoe	Mussel
Problema bulenta	Rare Skipper	Butterfly
Toxolasma pullus	Savannah Lilliput	Mussel

CHAPTER 2: LITERATURE REVIEW

PRE-COMPLIANCE CONSERVATION

The Endangered Species Act (ESA) states that the process of listing or delisting a species is to be "based solely on the best scientific and commercial data available" (ESA §1355(b)(1)(A)). In reality, political and economic considerations are frequently taken into account and environmental or species protection is characterized as contradictory to economic development (Meyer 1998, Lorah and Southwick 2003). Political battles can significantly delay the listing process, resulting in inadequate protection for imperiled species. In certain cases, some species have even gone extinct while on the ESA waiting list (Ando 1999).

Pre-compliance conservation, or pre-listing, directs conservation efforts towards species with inadequate protection. Under these efforts, conservation managers work cooperatively with landowners to conserve unprotected species; landowners volunteer to undertake mitigation efforts or land use restrictions on their land in exchange for various types of compensation. This cooperation and early action provides flexibility when crafting management plans, ensuring the protection of landowner interests while effectively preserving target species.

Several federal agencies, including FWS and the Bureau of Land Management (FWS 2011, Giblin 2012), are currently investigating pre-compliance strategies. FWS is even considering altering ESA regulations to incorporate preemptive conservation plans (DOI 2012a). Non-governmental organizations, such as EDF, can also develop management plans with landowners, either independently or as mediators between landowners and the government (Bean et al 2001, Demers and Carter 2004).

INCENTIVES FOR PRE-COMPLIANCE CONSERVATION

Pre-compliance conservation provides several benefits to conservation managers. Preemptive conservation is preferred over "reaction based" conservation (Spring et al 2007), especially given the uncertainty species face due to climate change (Marris 2008). Private lands often contain more threatened species than federal lands, necessitating the involvement of private actors (Wilcove et al 1996, Groves et al 2000). Conservation efforts can be more productive when this involvement is cooperative rather than confrontational. Involving private landowners also provides firsthand knowledge of the lands that can prove valuable when designing management plans (Innes and Frisvold 2009).

Pre-listing has the potential to conserve far more species than can possibly be officially listed. The average time between a species becoming a candidate for conservation and a listing decision is 17 years (Greenwald and Suckling 2005). Opponents question the scientific rigor and credibility of the listing process (D'Elia and McCarthy 2010), allowing politics and economics to influence decisions that are meant to be entirely scientific (Platt 2011, Ando 1999). This delay creates an enormous backlog of species overwhelming FWS (Schwartz 2008; Woody 2011). As a result, species chronically receive less protection than they require: 80% of IUCN-listed amphibians and 88.9-95.2% of IUCN-recognized invertebrates are in ESA protection categories below what is recommended by IUCN (Harris et al 2012).

FWS is consistently denied the resources required to implement the ESA fully, exacerbating their inability to provide the protections species need (Schwartz 2008). One of the primary reasons FWS identifies candidate species is to encourage the participation of other interested parties and reduce their burden (FWS 2011b). FWS hopes that focusing conservation efforts on species prior their listing may eventually make a listing unnecessary, alleviating the species backlog (DOI 2012b).

Any tool that changes private landowner behavior has three essential components: demand for action, supplied opportunities, and an infrastructure in which the landowner can act. The type of conservation agreement provides the infrastructure, and the conservation manager provides the supply by offering the opportunity to cooperate. Under traditional, post-compliance conservation, landowner demand for conservation is created by the restrictions and penalties faced under regulated protection; these are absent from pre-compliance. Instead, a desire to avoid future regulations should protection be granted provides the main source of landowner demand for pre-listing.

The desire to avoid harm to imperiled species in order to prevent a listing can be seen in Union County, N.C. The North Carolina Turnpike Authority (NCTA) is proposing a road known as the Monroe Bypass. This project has large economic implications; its completion is expected to create over 20,000 jobs (Harrison 2012). However, development has been halted over environmental issues, including concerns over the federally protected Carolina heelsplitter (*Lasmigona decorata*). NCTA commissioned a survey on the freshwater mussels in the area in response to these concerns. Importantly, the survey included the Atlantic pigtoe (*Fusconaia masoni*) and the Savannah liliput (*Toxolasma pullus*), two non-regulated mussel species. While these species are not currently protected, they were included for the explicit reason that "[these species] may be listed in the near future." (Catena Group 2009)

Pre-compliance conservation can also avoid the perverse incentives that accompany formal protection. The benefits of species protection are not proportionately distributed with the costs faced (Hanley et al 2006); while the benefits are distributed across society, the costs of protection are felt almost entirely by the landowners (Michael 2000). Landowners often respond to a species listing by intentionally degrading the habitat quality of their land (Brook et al 2003, Michael 2000). This "Shoot, Shovel, and Shut up" approach attempts to drive the listed species from the land and reduce the regulatory burden on the landowner. Pre-listing can provide landowners with compensation for the environmental services they provide, removing these perverse incentives.

Pre-listing gives landowners greater input when designing a management plan, and can therefore incorporate their interests (FWS 2011). Landowners invited to participate in the process are more likely to feel that their knowledge is being valued, and that conservation planners are concerned over the costs they face; this develops trust between the landowner and conservation manager, making the landowner more willing to cooperate

(Womack 2008). Landowner involvement also provides a “first mover advantage;” should the target species eventually become protected, a pre-existing management plan can make future restrictions less burdensome. Landowners who volunteer for pre-compliance measures can also be protected from any additional regulations following protection (Zaffos 2012). Landowners are more likely to participate in conservation efforts when assurances are provided, especially when assurances are combined with compensation (Langpap 2006).

CONSERVATION STRATEGIES

Despite the lack of formal legal protections, pre-compliance programs can simulate established post-compliance conservation programs (Noss et al 1997). These programs use a variety of policy tools that influence the types of incentives provided to landowners, the means of identifying landowners to undertake the mitigation efforts, the permanence of the protections provided, and a variety of other components. Some of these programs are discussed below:

Conservation Exchange Markets

Conservation exchange markets are a common mitigation strategy. Conservation exchange markets invert the perverse incentives facing landowners by making habitat conservation profitable (Bonnie 1999). If managed properly, markets can conserve large, continuous areas while allowing development on highly fragmented habitats with little ecological value (Bonnie 1999).

One market example, conservation banking, allows landowners to receive credits in exchange for conducting habitat restoration. These credits can then be sold to other landowners who need to offset negative impacts from land uses or development. Conservation banks have typically been used to conserve protected species, with regulated demand to offset impacts (for an example, see Wolfe et al 2012). A similar approach can be used to conserve non-protected species if there is sufficient desire within a community to avoid future regulations.

Wetland mitigation is another type of conservation exchange market. Section 404 of the Clean Water Act (CWA) requires actors to compensate for wetland destruction through the restoration or creation of additional wetlands (CWA 33 U.S.C. § 1344). This is commonly expected to comply with the U.S. policy of “no net loss” of wetland acreage (Votteler and Muir 1996). While wetland mitigation is not “pre-compliance” (CWA requires this mitigation), it can still benefit the non-protected species occupying the wetlands.

Reverse Auctions

Under reverse auctions, landowners submit bids to conservation managers detailing the level of conservation they could undertake for a certain price; this price is based on the expected cost of implementation (Hanley et al 2012). Conservation managers select the bid that provides the greatest conservation values for the lowest cost. Whereas traditional auctions involve competing demanders driving up prices, a reverse auction has competing suppliers driving down prices.

Safe Harbor Program

The Safe Harbor program removes the perverse incentives from conducting habitat improvement (Bonnie 1999). These are formal agreements between a landowner and FWS, under which the landowner may improve habitat quality without fear of future regulations. The parties establish a baseline level of habitat quality before the landowner undertakes conservation actions. Without the landowner's consent, FWS cannot subject the landowner to additional restrictions beyond the terms of the agreement, even if the conservation efforts attract additional protected species (Noss et al 1997). At the end of the agreement period, the landowner may stop the conservation measures and return the habitat to its baseline quality.

Traditionally, the Safe Harbor program is used to conserve protected species (for an example, see DOI 2012c). Its policy components, however, can also conserve non-protected species if the landowner agrees to conservation measures that won't increase should the species eventually become protected.

Conservation Easements

Conservation easements split a land title and provide separate parties with control over different land uses. While the land remains primarily under control of the original landowner, the conservation manager can now prohibit or control the land uses it owns, such as development (Jordan 1993). The landowner receives payment for the land rights sold, and may only have to pay taxes on the "remaining value of the land." (Merlander et al 2004)

Beyond this basic structure, the specific terms of an easement are flexible, and may vary from case to case. Restrictions on land use can remain even if the landowner sells the property, as the easement holder retains its portion of the land title. Easement protections are therefore intended to be "perpetual" (although this is not always the case: see Jay 2012, Jordan 1993).

Habitat Conservation Plans

Section 10 of the ESA allows FWS to permit an activity that involves some take of an endangered species so long as the actors enter into a Habitat Conservation Plan (HCP). HCPs therefore exchange some species loss for permanent protection or mitigation measures. HCPs can constitute many types of management plans, including both on-site and off-site mitigation and the creation of reserve networks (Bonnie 1999); they are adaptable to the needs of the species and the characteristics of the habitat.

HCPs benefit species that require direct and proactive management, rather than passive restrictions on land use or take (Schwartz 2008). However, there are some limitations to HCPs. They are subject to the "no surprises" doctrine, which assures landowners that they will not be subject to additional restrictions, even if the original plan proves insufficient (Kostyack 1998). This restricts conservation management if circumstances change or new information is discovered; it is especially concerning since the science used to design HCPs isn't always sound (Harding et al 2001).

CHAPTER 3: METHODS

IDENTIFYING TARGET SPECIES

The species targeted in this project are unprotected yet imperiled aquatic or wetland animals occurring in North Carolina. A press release from the Center for Biological Diversity identified 49 potential species (CBD 2011). I removed eight of these species from the analysis when I discovered that they did not actually occur in North Carolina; I removed an additional eight for which I could not find spatial data. I removed three final species (*Laterallus jamaicensis*, *Myotis leibii*, and *Myotis septentrionalis*) with life history traits inconsistent from the other species. While these species utilize wetland areas, they have a widespread distribution beyond the southeastern U.S., and are drastically more mobile than the other target species.

CREATING REGIONAL GROUPINGS

The North Carolina Natural Heritage Program provided element occurrence (EO) data for the target species (NHP 2012) and data on federal land ownership (NHP 2013). The Multi-Resolution Land Characteristics Consortium provided land use/land cover data (MRLC 2006). The U.S. Department of Agriculture (North Carolina Natural Resources Conservation Service State Office) provided data on hydrologic units (USDA 2008). The North Carolina Center for Geographic Information and Analysis provided data on county boundaries (NCCGIA 2006). The National Atlas of the United States provided data on roads (National Atlas 1999). The National Inventory of Dams provided data on impoundments (USACE 2010). The National Hydrography Dataset provided data on hydrography, elevation and other landscape characteristics (NHD 2005). Esri provided the topographic map used in several of the figures found in this report; this map compiles the contributions of a large community of experts and GIS users as the "World Topographic Map" (ESRI 2013). All data was re-projected to Albers (North American Datum 1983), if necessary. All spatial analyses were conducted using ArcGIS 10.1 (ESRI 2012).

The target species occur throughout North Carolina (Figure 1). In order to identify discrete regions in which EDF could implement pre-compliance programs, I organized the EO points into four geographic groupings on the basis of spatial proximity, dominant land uses, and elevation (see Figure 2 on page 11).

SPATIAL THREAT ANALYSIS

I mapped five potential stressors to assess the threats facing the target species: agriculture, development, deforestation, roads, and river impoundments. I used a "Test" tool to derive agriculture, development, and deforestation from land use/land cover data.

I then assigned threat levels for all five stressors to each EO point. For agriculture, development, and deforestation, I used a "Focal Statistics" tool to determine the densities of these land covers (or in the case of deforestation, the absence of forest cover) within a 5 km radius of the EO point. I used a "Line Density" tool to determine the road density within 5 km of each EO point.

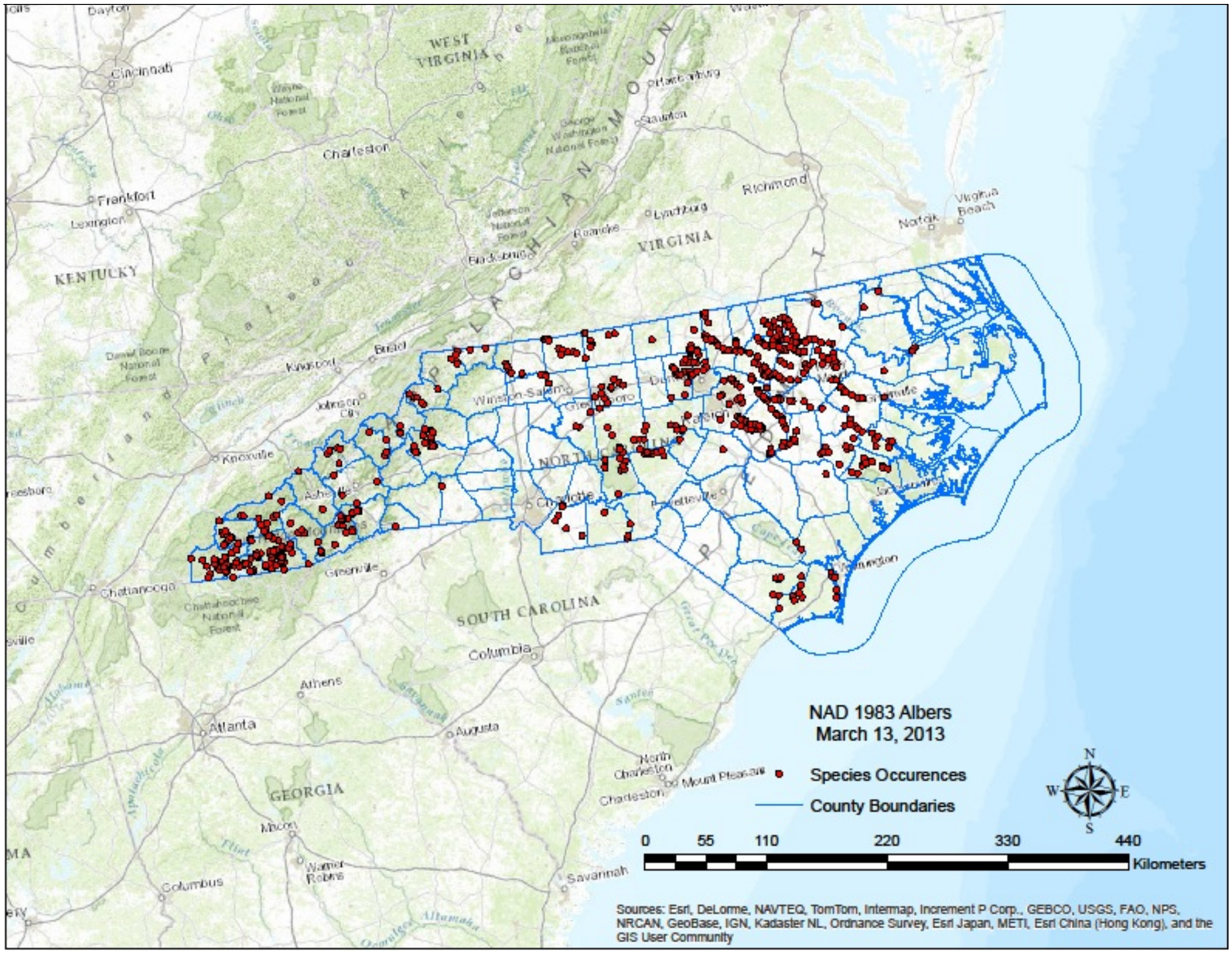

Figure 1: Element Occurrences of Target Species

I used a "Network Analysis" tool to determine the nearest upstream dam from each EO point. These distance measures were not Euclidean; rather they were measured along the hydrographic network in river kilometers (rkm). The downstream distance from a dam at which ecological conditions reset is variable. Generally, however, the impacts from impoundments attenuate with increasing downstream distance. I measured dam impacts within 100 rkm downstream. While thermal impacts have been detected as far as 950 rkm from a dam (Stanford and Ward 2001), most of the EO points with upstream dams occurred within 100 rkm of that dam. Furthermore, I did not want to obscure potentially large differences in flow conditions that can occur within the first hundred kilometers in order to capture any fleeting impacts within 1000 rkm out. Impoundment impacts decreased linearly as distance from the nearest upstream increased until 100 rkm was reached, at which point impacts were considered negligible.

I averaged the EO threat scores within species in each region, to determine the main threats facing individual species within each region.

POLICY ANALYSIS

I analyzed management strategies, whether pre- or post-compliance, that are commonly used to reach conservation agreements with landowners. These strategies included: conservation banking; wetland mitigation; reverse auctions; safe harbor agreements; conservation easements; and habitat conservation planning. I identified the policy decisions that were made in the development of each strategy. Together, these policy decisions comprised the policy toolkit (see Table 8 on page 18). For each policy tool, I considered the various alternatives that could be selected for a conservation agreement.

I conducted a literature review on the five primary threat sources to identify the main ecological impacts produced by each stressor. I identified at least one mitigation strategy that is commonly used to address each ecological impact. I compiled the mitigation strategies that might be used to address the major threat(s) facing each region. I then analyzed which policy alternatives from the policy toolkit best align with each mitigation technique. This produced a list of mitigation techniques and policy tools that might be used within a geographic region.

ECOLOGICAL ANALYSIS OF LIFE HISTORY TRAITS

I conducted an analysis on the life history characteristics of the species within each geographic region. This ensured that the mitigation techniques and policy tools utilized in that region will align with the dominant life history patterns of its constituent species.

A review of ecosystem assessments and wildlife action plans identified relevant life history traits that conservation policies attempt to account for (NCWRC 2002; NCWRC 2005; NCDENR 2010). I conducted a literature review on the 30 target species to obtain ecological data for these life history traits. Whenever possible, I tried to minimize the number of sources I collected ecological data from in order to maintain consistency within the data (NatureServe 2013; CBD 2010). It was occasionally necessary to conduct a further literature review to find data when it was not included in my two main sources (Parmalee and Bogan 1998; Johnson 1970; Simmons and Fraley 2010; Cooper and Braswell 1995; Jelks et al 2008; Midway et al 2010; Angermeier 1995; Simonson and Neves 1992; Grabowski and Isley 2006; FWS 2010; Sandel and Harris 2007; Dunkle 2000; SCDNR 2005; USGS 2013, EPA 2013). If the required ecological data could not be found for a species in the literature, I approximated the data through an analysis of closely related species (Tree of Life 2013; Campbell et al 2005; Taylor and Hardman 2002).

I coded all ecological variable categorically. Condensing data into categories can limit the inherent uncertainty in the data. The literature on these species may not be able to provide, for example, a specific level of mobility; it may instead indicate an estimated range for mobility, or approximate values based on the species' taxa. Clustering species by quantitative variables might therefore accentuate small differences that have limited basis in reality. For the purposes of this project, identifying broad-scale patterns was more important than recognizing subtle differences between species; it was therefore sufficient to categorize mobility by orders of magnitude.

I analyzed the natural groupings within the data by generating histograms, and coded the data to reflect these groupings. Coding determinations can be seen in Table 2.

TABLE 2: Life History Codes

Ecological Variable	Data Range	Code
Endemism*	*25-123 watersheds*	1
	12-24 watersheds	2
	4-11 watersheds	3
	1-3 watersheds	4
Habitat Specificity**	*"Moderate to Broad," "Broad"*	1
	"Narrow to Moderate," "Moderate"	2
	"Narrow"	3
	"Very Narrow," "Very Narrow to Narrow"	4
Mobility	*0-9 meters*	1
	10-99 meters	2
	100-999 meters	3
	1000 meters or higher	4
Migratory Habits	*Non-migratory*	0
	Migratory	1
Interspecific Association***	*No*	0
	Yes	1
Habitat Variation by Life Stage	*No*	0
	Yes	1

*=Determined by the number of watersheds the species occurs in
**=Base on NatureServe's (2013) categories for Habitat Specificity
***=Determined by whether there are specific species relied upon by the target species as food, habitat, or as a host species

For the species within each region, I organized the coded data into matrices with columns of ecological variables and rows of species. In PC-ORD 6 I conducted a clustering analysis (McCune and Mefford 2011), using Euclidean Distance as the distance measure and Ward's methods (Ward 1963) as the group linkage method. This process organized species into ecologically similar groups and identified dominant life history patterns for each geographic region.

I considered the challenges or complexities that each life history trait might present to a conservation manger developing a pre-compliance program. In some cases these species characteristics may limit the policy tools that can be used. I analyzed how the dominant life history traits of each geographic region might limit or exclude the mitigation techniques or policy tools identified as potentially useful for each region.

CHAPTER 4: RESULTS

SPATIAL THREAT ANALYSIS

The target species occur throughout North Carolina (Figure 1). Occurrences organize into four main geographic regions (Figure 2), on the basis of spatial proximity, land use (Figure 3a), and elevation (Figure 3b). Species located in the same geographic region tend to face similar threat sources; this presents an opportunity for localized conservation programs that target these shared threats.

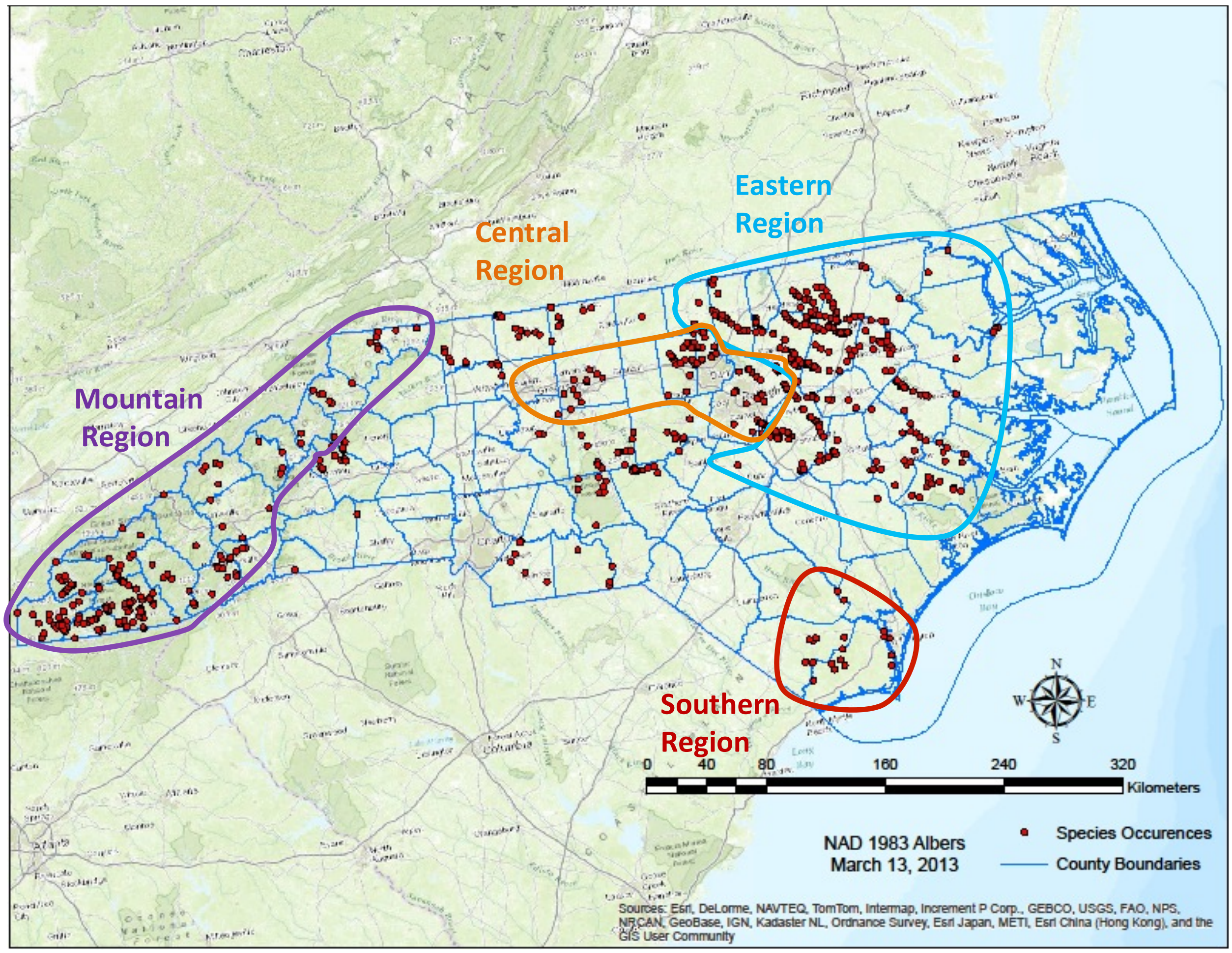

Figure 2: Geographic Regions

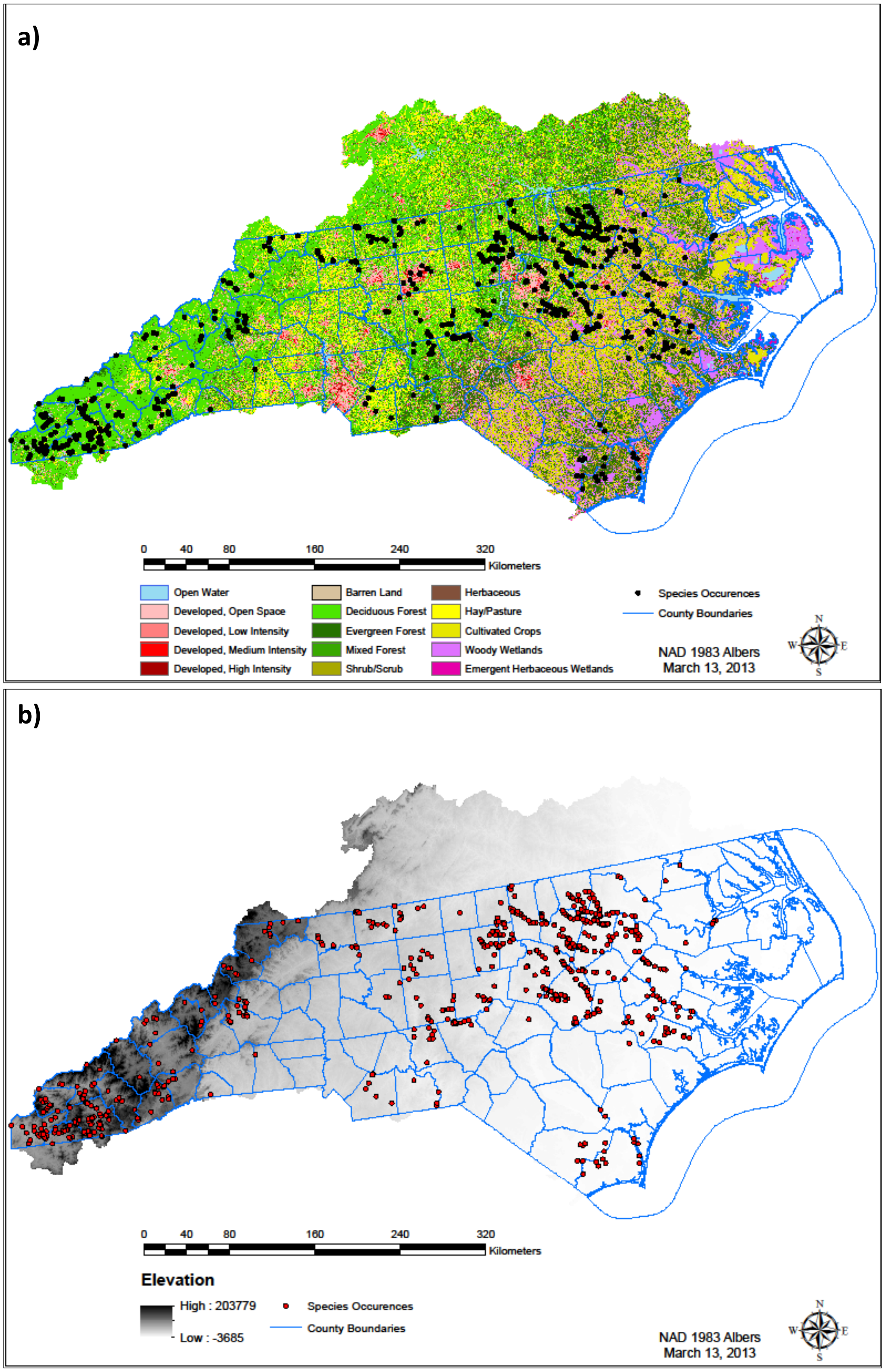

Figure 3: Determinants of Geographic Groupings. (a) Land use. (b) Elevation.

The information in Tables 3-7 is derived from the spatial threat analysis; further information is available in Appendix I. The Mountain Region occurs in the high elevation regions along the western edge of the state (Figure 2). River and stream impoundment from dams is the primary threat facing these populations (Table 3).

TABLE 3: Threats to Mountain Region Species

Species	Agriculture	Development	Deforestation	Roads	Impoundment
C. chaugaensis [Crayfish]	Very Low	Low	Very Low	Low	Very High
M. sp2 [Fish]	Low	Low	Low	Low	High
P. gibberum [Mussel]	Low	Low	Low	Moderate	High
C. georgiae [Crayfish]	Moderate	Low	Low	Low	Moderate
C. alleganiensis [Salamander]	Moderate	Low	Low	Moderate	Moderate
M. margarita [Dragonfly]	Moderate	Low	Low	Low	Moderate
L. subviridis [Mussel]	Moderate	Very Low	Low	Low	Moderate
F. subrotunda [Mussel]	Moderate	Low	Low	Very Low	Very High
P. oviforme [Mussel]	Moderate	Moderate	Low	Low	Very High
L. holstonia [Mussel]	High	Moderate	Moderate	Moderate	Very High
C. parrishi [Crayfish]	Low	Very Low	Very Low	Very Low	Low
D. aeneus [Salamander]	Very Low	Very Low	Very Low	Very Low	Low
O. edmundo [Dragonfly]	Very Low	Very Low	Very Low	Very Low	High
M. williamsae [Stonefly]	Very Low	Very Low	Very Low	Moderate	Very Low

The Central Region occurs in the highly developed Triad and Triangle regions (Figure 2). Stressors associated with urbanization, such as development, deforestation, and roads, strongly threaten these populations. Impoundments are also a primary threat source in this area (Table 4).

TABLE 4: Threats to Central Region Species

Species	Agriculture	Development	Deforestation	Roads	Impoundment
A. varicosa [Mussel]	Moderate	Moderate	Moderate	Moderate	Very Low
C. catagius [Crayfish]	Low	Very High	High	Very High	Low
E. lanceolata [Mussel]	High	Moderate	High	Very High	Very High
F. masoni [Mussel]	High	Moderate	Moderate	Moderate	High
L. subviridis [Mussel]	High	Moderate	Moderate	High	Very High
N. lewisi [Salamander]	Moderate	High	Moderate	Moderate	Very High
T. pullus [Mussel]	Low	High	Moderate	High	Very High
G. septima [Dragonfly]	Low	Very High	Moderate	High	Very High
N. furiosus [Fish]	Low	Very High	High	Very High	Very High

The Eastern Region occurs in the rural areas to the east of the Triangle (see Figure 2). Agriculture is the primary threat to these populations (Table 5).

TABLE 5: Threats to Eastern Region Species

Species	Agriculture	Development	Deforestation	Roads	Impoundment
A. varicosa [Mussel]	High	Very Low	Moderate	Moderate	Moderate
E. lanceolata [Mussel]	High	Low	Moderate	Moderate	Very High
F. masoni [Mussel]	High	Low	Moderate	Moderate	High
N. furiosus [Fish]	Very High	Low	High	Moderate	High
N. lewisi [Salamander]	Very High	Low	High	Moderate	High
O. virginiensis [Crayfish]	High	Very Low	Very High	Moderate	Moderate
L. subviridis [Mussel]	High	Moderate	Moderate	High	High

The Southern Region occurs in the southeast corner of the state (see Figure 2). Low forest cover is the primary threat to these populations (Table 6).

TABLE 6: Threats to Southern Region Species

Species	Agriculture	Development	Deforestation	Roads	Impoundment
E. boehlkei [Fish]	Low	Very Low	High	Very Low	Low
F. masoni [Mussel]	Moderate	Very Low	High	Moderate	Moderate
L. fullerkati [Mussel]	Moderate	Very Low	Moderate	Moderate	Moderate
T. pullus [Mussel]	Moderate	Very Low	Moderate	Moderate	Moderate
P. magnifica [Snail]	Low	High	High	High	Low
P. bulenta [Butterfly]	Very Low	High	Very High	Very High	Very Low

Each main threat source has characteristic ecological impacts that require mitigation (see Table 7 on page 17 for a summary of impacts and mitigations). Agricultural regions threaten aquatic ecosystems with non-point source (NPS) runoff of nutrients, chemicals, and sediment (Vellidis et al 2003, EPA 2005). Agricultural runoff can be mitigated through the development of riparian buffers and other landscape features such as retention basins (Vellidis et al 2003, Vought et al 1995). It can also be alleviated through the adoption of best management practices (BMP) regarding the application of fertilizers or livestock waste management (Vellidis et al 2003, EPA 2005). Agricultural practices can also result in heavy erosion (Vellidis et al 2003). BMP, such as conservation tillage, intercropping, and time-controlled grazing, help reduce erosion (McLaughlin and Mineau 1995, EPA 2005, Sanjari et al 2009). Agricultural practices can also overuse water; this can be particularly detrimental in areas like the southeastern U.S. that have a history of droughts (Seager et al 2009). Water overuse can be mitigated through the adoption of BMP and conversion to more efficient irrigation technologies such as drip irrigation (Bos and Bergkamp 2001, Playán and Mateos 2006).

Agriculture also causes habitat loss as aquatic areas are degraded or converted through practices such as drainage (Blann et al 2009). Off-site wetland mitigation can be used to compensate for this habitat loss. While CWA doesn't require all farming activities resulting in habitat loss to be mitigated (see EPA 2012), compensation can still be conducted in a pre-compliance context.

Urban development increases impervious surfaces, resulting in storm water runoff that is harmful to aquatic species (Gillies et al 2003). While no single strategy employed in isolation may be sufficient, this can be mitigated through a combination of riparian buffering, constructing landscape features such as retention ponds, and replacing impervious surfaces with permeable paving (Booth et al 2002, Brattebo and Booth 2003). Urban pollution can also cause habitat loss or degradation. This can be mitigated through ongoing stream restoration efforts (Charbonneau and Resh 1992). BMP can also reduce pollution effects (D'Arcy and Frost 2001).

Deforestation degrades water quality through increased sedimentation, siltation, and a decreased ability to prevent nutrient runoff (Beechem 2008, Hunsaker and Levine 1995). Riparian buffering can help prevent this runoff from reaching streams (Lorion and Kennedy 2009). Deforestation also reduces the amount of woody debris and leaf litter introduced into aquatic habitats, increasing habitat homogeneity (Beechem 2008, Wright and Flecker 2004). This can be mitigated through stream restoration measures that reintroduce debris into these habitats, or by creating woodland buffer strips (Gurnell et al 1995). Loss of forest cover exposes streams to more sunlight and radiation, increasing water temperatures (Brown and Krygier 1970, Hetrick et al 1998). Increased temperatures can be mitigated by constructing shade covers for streams and rivers or by establishing riparian buffers (Fink 2008, Osborne and Kovacic 1993).

Road development results in runoff from chemicals, road salts, and sediment (Forman and Alexander 1998). This runoff can be mitigated through the development of riparian buffers and other landscape features such as retention basins (Ziegler et al 2006). Surface erosion at the edge of roads can result in sedimentation and potential landslides (Williams 1999). This can be mitigated through erosion control measures, such as planting native vegetation and using wire netting on barren roadsides (Grace 2002, CADOT 2013). Roads construction is often correlated with increased water temperature (Williams 1999). Stream shading techniques, such as shade covers and riparian buffering, can reduce temperatures (Fink 2008, Osborne and Kovacic 1993). Invasive species can spread along roads and other disturbances (FICMNEW 1998, Zedler and Kercher 2004). This can be mitigated through targeted invasive species removal (Kettenring and Adams 2011).

Impoundments cause an alteration in downstream flow conditions, such as oxygen levels, water temperature, and stream substrate (Lessard and Hayes 2003, Ward and Stanford 1987). Dams can be modified or retrofitted to allow for a more natural stream flow while retaining most of the dam's original functionality (WWF 2004). Dams can also present migratory barriers to fish (Larinier 2001). This can be mitigated through similar retrofitted modifications that allow for species passage (WWF 2004). Dams can also cause habitat destruction through habitat inundation or the deepening of river beds (Layzer et al 1993). This can be mitigated by compensating for this through off-site mitigation (WWF 2004).

The main ecological impacts associated with each threat, and the strategies that can be used to mitigate them, are summarized in Table 7.

POLICY ANALYSIS

An analysis of currently used management strategies identified their composite policy tools, or the decisions that must be made when developing a strategy. For each policy component, at least two alternatives were identified. These policies and alternatives form the policy toolkit (see Table 8 on page 18).

TABLE 7: Mitigation Strategies

Agricultural Impact	Agricultural Mitigation Strategy
NPS Runoff from Chemicals, Sediment, and Livestock	Establish riparian buffers, retention basins, or other landscape features Adopt BMP
Erosion and Sedimentation	Adopt BMP
Water Overuse	Adopt BMP Improve technology
Habitat Loss	Conduct off-site restoration

Development Impact	Development Mitigation Strategy
Runoff from Impervious Surfaces	Establish riparian buffers, retention basins, or other landscape features Modify existing development
Habitat Degradation	Stream restoration Adopt BMP

Deforestation Impact	Deforestation Mitigation Strategy
Siltation and Runoff	Establish riparian buffers
Loss of Woody Debris and Leaf Litter	Stream restoration Establish riparian buffers
Increased Water Temperature	Conduct artificial stream shading Establish riparian buffers

Road Impacts	Road Mitigation Strategies
Runoff from Road Chemicals and Salts	Establish riparian buffers, retention basins, or other landscape features
Erosion and Sedimentation	Conduct erosion control measures
Increased Water Temperature	Conduct artificial stream shading Establish riparian buffers
Invasive Species Spread	Conduct targeted invasive species removal

Impoundment Impacts	Impoundment Mitigation Strategies
Altered Stream Flow	Modifications to existing dams
Migration Barriers	Modifications to existing dams
Habitat Loss	Conduct off-site restoration

TABLE 8: Policy Toolkit

Policy	Alternative	Comments
Mitigation Timeframe	Temporary	Mitigation requiring continuous effort or upkeep, or which requires a loss to property, will require temporary protections that the landowner can end if they become too onerous.
	Permanent	Mitigation requiring an initial investment of resources but not continuous may be able to provide permanent protections to the target species.
Mitigation Location	On-Site	Landowners may mitigate any impacts from their land use by creating, conserving, or restoring habitat at the site of the impact. This is typically not conducive to a conservation exchange program.
	Off-Site	Landowners may mitigate any impacts from their land use by creating, conserving, or restoring habitat removed from the site of the impact. This is typically conducive to a conservation exchange program.
Mitigation Scale	Narrow	Mitigation that can be effective with a limited number of enlisted landowners can be conducted on a narrow landscape scale.
	Broad	Mitigation that will be ineffective if an insufficient number of landowners enlist must be conducted on a broad landscape scale.
Management	Active	Active management requires the landowner or conservation manager to undertake specific action to restore and preserve habitat.
	Passive	Passive management requires the restriction of certain land uses.
Landowner Incentives	Assurances: Baseline Habitat Quality (BHQ)	Landowners can be incentivized to enlist by establishing a baseline level of habitat quality at the onset of an agreement. Landowners may then return the habitat to its baseline quality at the end of the agreement. This is typically conducive with temporary protections.
	Assurances: No Additional Restrictions (NAR)	Landowners can be incentivized to enlist by being protected from any additional restrictions should the target species become legally protected. This is typically conducive with permanent protections that cannot be removed once the landowner receives the assurance.
	Direct Payments: Continuous (e.g. Tax Benefits)	Landowners can be incentivized to enlist through receipt of direct payments that continue to the length of the agreement. These are conducive with temporary protections. In the case of conservation easements, these payments can be in the form of tax benefits.
	Direct Payments: One-Time	Landowners can be incentivized to enlist through receipt of one-time direct payments. These are typically conducive to permanent protections that cannot be removed once the payment is received.
Conservation Easements	Yes No	Partial land rights to the property can be purchased from the landowner, giving the conservation manager control over certain types of land use.
Conservation Exchange Markets	Yes No	A trading or banking program allows landowners to mitigate their environmental impact by purchasing conservation credits from other landowners who, in turn, conduct habitat creation, conservation, or restoration.
Reverse Auctions	Yes No	Reverse auctions allow limited funds for conservation to be spent flexibly and efficiently. Reverse auctions are unable to target specific habitat areas.

While there is occasionally some flexibility, different policy alternatives tend to align with certain mitigation techniques (see Table 9 on page 21). Construction of riparian buffers and other landscape features such as retention ponds requires a large, initial investment in resources; these protections are therefore permanent in nature. Incentives conducive with permanent protections, such as NAR assurances or one-time direct payments, could be used. Since these are conducted on-site, an exchange program would not be appropriate. A reverse auction, however, will help identify the landowners who can most efficiently establish the required landscape features.

While it is possible that land uses or management practices could be changed permanently, adopting BMP is temporary in nature, as it requires a continual effort that landowners could cease at any time. Incentives conducive to temporary protections, such as BHQ or continuous payments, could be used. Conservation easements that obtain the rights to certain land uses could be a very effective means of altering management practices, and could provide continuous payments to the landowners. Reverse auctions can identify landowners who can adopt new practices effectively and efficiently. These protections are conducted on-site, and would therefore preclude an exchange market.

Updating technology mainly requires an initial investment of resources; these protections are therefore permanent in nature. Incentives conducive with permanent protections, such as NAR assurances or one-time direct payments, could be used. Since these are conducted on-site, an exchange program would not be appropriate. A reverse auction, however, will help identify the landowners who can most efficiently update their infrastructure.

Off-site restoration can be conducted through an exchange market. Mitigating a permanent source of harm should require the purchase of permanent habitat protections or restoration elsewhere. The mitigation conducted may involve either active or passive management. Neither conservation easements nor reverse auctions are conducive with off-site mitigation.

Modifying existing development requires a large initial investment in resources; this therefore represents a permanent protection. Incentives conducive with permanent protections, such as NAR assurances or one-time direct payments, could be used. Since modifications are conducted on-site, an exchange program would not be appropriate. A reverse auction, however, will help identify the landowners who can most efficiently conduct the required modifications.

Dam retrofits require a large initial investment, can be costly and difficult to reverse, and would therefore likely be considered a permanent protection. However, the modifications required to naturalize stream flow conditions decrease dam functionality, representing a continual loss of value to the dam operator. Therefore, while this is a permanent protection, it may be suitable for long term payments or a conservation easement. Such a program would need to be broad in scale, as the impacts of multiple dams can compound. Reverse auctions will help identify dam operators who can install the modifications most efficiently.

Habitat or stream restoration, such as the reintroduction of woody debris, can require continual efforts or upkeep; these protections are therefore temporary in nature. Incentives conducive with temporary protections, such as BHQ assurances or continuous payment, could be used. Conservation easements could provide continuous payments to the landowners. Restoration of the impacted area requires on-site mitigation, precluding conservation exchange markets. Reverse auctions can provide an effective means of identifying landowners who can most efficiently provide restoration.

Most of the resources required for artificial shade covers are invested upfront; these protections are therefore permanent in nature. Incentives conducive with permanent protections, such as NAR assurances or one-time direct payments, could be used. Stream shading can be conducted on-site using reverse auctions to identify landowners who can implement these shades efficiently.

Erosion control requires continuous upkeep; landowners may want the option to exit from this agreement, making this a temporary protection. Incentives conducive with temporary protections, such as BHQ assurances or continuous payment, could be used. Conservation easements could provide continuous payments to the landowners. Erosion control can be conducted as either on-site or off-site mitigation. With off-site mitigation, a conservation exchange market can be established. With on-site mitigation, a reverse auction can be used.

Invasive species control is a continuous process, and as such any protection provided can only be temporary. Conservation easements are possible, but reverse auction are probably unnecessary as it is unlikely one landowner could achieve significantly more efficient invasive removal. Invasive control can be conducted as either on-site or off-site mitigation; with off-site, a conservation exchange market can be established.

The alignment of policy tools to mitigation techniques is summarized in Table 9.

TABLE 9: Appropriate Policy Responses for Mitigation Techniques

Mitigation	Policy Alternatives	
Construction of Riparian Buffers, Diversion Systems, or Landscape Features	Timeframe	Permanent
	Location	On-Site
	Management	Active
	Incentives	NAR or One-Time Payment
	Conservation Easements	No
	Exchange Markets	No
	Reverse Auctions	Yes
Best Management Practices	Timeframe	Temporary
	Location	On-Site
	Management	Passive
	Incentives	BHQ and/or Continuous Payments
	Conservation Easements	Yes
	Exchange Markets	No
	Reverse Auctions	Yes
Technology Improvements	Timeframe	Permanent
	Location	On-Site
	Management	Active
	Incentives	NAR or One-Time Payment
	Conservation Easements	No
	Exchange Markets	No
	Reverse Auctions	Yes
Off-Site Habitat Restoration	Timeframe	Permanent
	Location	Off-Site
	Management	Active
	Incentives	NAR or One-Time Payment
	Conservation Easements	No
	Exchange Markets	Yes
	Reverse Auctions	No
Modification to Existing Development	Timeframe	Permanent
	Location	On-Site
	Management	Active
	Incentives	NAR or One-Time Payment
	Conservation Easements	No
	Exchange Markets	No
	Reverse Auctions	Yes

TABLE 9 (cont.): Appropriate Policy Responses for Mitigation Techniques

Mitigation	Policy Alternatives	
Modification to Existing Dams	Timeframe	Permanent
	Location	On-Site
	Management	Active
	Incentives	Continuous Payments
	Conservation Easements	Yes
	Exchange Markets	No
	Reverse Auctions	Yes
On-Site Stream Restoration	Timeframe	Temporary
	Location	On-Site
	Management	Active
	Incentives	BHQ and/or Continuous Payments
	Conservation Easements	Yes
	Exchange Markets	No
	Reverse Auctions	Yes
Artificial Stream Shading	Timeframe	Permanent
	Location	Either
	Management	Active
	Incentives	NAR or One-Time Payment
	Conservation Easements	No
	Exchange Markets	Yes (if Off-Site)
	Reverse Auctions	Yes (if On-Site)
Erosion Control	Timeframe	Temporary
	Location	Either
	Management	Active
	Incentives	BHQ and/or Continuous Payments
	Conservation Easements	Yes
	Exchange Markets	Yes (with Off-Site)
	Reverse Auctions	Yes (with On-Site)
Targeted Invasive Species Removal	Timeframe	Temporary
	Location	Either
	Management	Active
	Incentives	BHQ and/or Continuous Payments
	Conservation Easements	Yes
	Exchange Markets	Yes (with Off-Site)
	Reverse Auctions	No

ECOLOGICAL TRAIT ANALYSIS

The following traits were determined to be of interest: level of endemism; habitat range; population size; level of habitat specialization; mobility (or dispersal distance); migratory habits; age to sexual maturity; fecundity; level of interspecific associations (e.g. a specific host species or food source); and habitat variation by life cycle.

Certain ecological traits present challenges or complexities to conservation managers designing a conservation strategy. In some cases these species characteristics may limit the extent to which certain strategies are taken, or may exclude certain strategies altogether. In other cases, species characteristics present an extra component conservation managers should consider when developing conservation strategies (Table 10).

TABLE 10: Considerations Required by Species Traits

Trait	Consideration	Consequence
Highly Endemic	Highly endemic species may require very specific areas to be conserved. With smaller ranges, a species is more likely to be extirpated by a single threat source .	Reverse auctions may still be used as long as they are confined within the species' geographic range.
Habitat Specialists	Habitat specialists require very specific habitat to be conserved or restored. Habitat specialists may be more susceptible to small changes to their habitats; if one key factors is changed, the habitat may become unsuitable.	Reverse auctions cannot be used for habitat specialists, as there is limited control over the habitat conserved.
Low Mobility	Species with low mobility may not be able to disperse to new habitat patches.	Off-site mitigation, conservation exchanges, and other strategies that restore habitat at a different site cannot be used for species with low mobility.
Migratory	Migratory species may require more than one location or habitat type to be conserved. Migratory species are especially susceptible to habitat fragmentation.	Conservation strategies targeting migratory species need to encompass their entire migratory route. Conservation strategies targeting migratory species need to target potential barriers to their migratory routes, such as roads and dams.
Interspecific Associations	If a species is highly reliant on an associate species, any threat that impacts the associate species will also threaten the target species.	A species that is highly reliant on another species would require its associate to be conserved as well.
Habitat Variation	A species with variable habitat requirements across its life cycle requires more than one habitat type to be conserved.	Conservation strategies targeting species with variable habitat requirements need to encompass each specific habitat type.

With the exception of Cluster 4, the species of the Mountain Region tend to be habitat specialists (Table 11). This limits the ability of using reverse auctions to identify private landowners to partner with, as the habitat targeted to conserve these species might be more specific. With the exception of Cluster 2, these species tend to have low mobility. This precludes the possibility of setting up conservation exchanges for these species, and requires mitigation techniques to be conducted on-site.

TABLE 11: Trait Clusters for Mountain Region Species

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Species	*C. chaugaensis* [Crayfish]; *C. parrishi* [Crayfish]; *C. georgiae* [Crayfish]	*M. margarita* [Dragonfly]; *M. williamsae* [Stonefly]; *O. edmundo* [Dragonfly]; *M. sp2* [Fish]	*C. alleganiensis* [Salamander]	*D. aeneus* [Salamander]; *L. holstonia* [Mussel]; *P. gibberum* [Mussel]	*F. subrotunda* [Mussel]; *L. subviridis* [Mussel]; *P. oviforme* [Mussel]
Endemism	Very High	High to Very High	Low	Moderate	Low
Habitat Specificity	Narrow	Narrow	Very Narrow	Moderate to Broad	Narrow to Moderate
Mobility	Low to Moderate	High	Low	Non-mobile to Low	Non-Mobile
Migratory Behavior	No	Variable	No	No	No
Interspecific Associations	No	Variable	No	Variable	Yes
Habitat Variability Through Life Cycle	No	Yes	No	No	No

Almost all of the species of the Central Region have low mobility (Table 12). Strategies conducted in the Central Region should utilize on-site over off-site mitigation. The species of the Central Region also tend to have narrow habitat requirements; this may discourage the use of reverse auctions, although there are a few exceptions to this.

TABLE 12: Trait Clusters for Central Region Species

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Species	*A. varicosa* [Mussel]; *F. masoni* [Mussel]	*E. lanceolata* [Mussel]; *L. subviridis* [Mussel]; *T. pullus* [Mussel]	*C. catagius* [Crayfish]	*G. septima* [Dragonfly]	*N. lewisi* [Salamander]; *N. furiosus* [Fish]
Endemism	Low	Low to Moderate	Very Narrow	High	High
Habitat Specificity	Narrow	Moderate	Moderate	Narrow	Narrow to Very Narrow
Mobility	Non-Mobile	Non-Mobile	Low	Moderate	Low
Migratory Behavior	No	No	No	No	No
Interspecific Associations	Yes	Yes	No	No	No
Habitat Variability Through Life Cycle	No	No	No	Yes	No

Almost all of the species of the Eastern Region have low mobility (Table 13). Strategies conducted in the Eastern Region should utilize on-site over off-site mitigation. The species of the Eastern Region also tend to have narrow habitat requirements; this may discourage the use of reverse auctions, although there are a few exceptions to this.

TABLE 13: Trait Clusters for Eastern Region Species

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Species	*A. varicosa* [Mussel]; *F. masoni* [Mussel]	*E. lanceolata* [Mussel]; *L. subviridis;* [Mussel]	*N. lewisi* [Salamander]; *N. furiosus* [Fish]	*O. virginiensis* [Crayfish]
Endemism	Low	Low	High	Very High
Habitat Specificity	Narrow	Moderate	Narrow to Very Narrow	Moderate
Mobility	Non-Mobile	Non-Mobile	Low	Low
Migratory Behavior	No	No	No	No
Interspecific Associations	Yes	Yes	No	No
Habitat Variability Through Life Cycle	No	No	No	No

While the species of the Southern Region also tend to be habitat specialists, this habitat specificity is less pronounced than it is in the other geographic groupings (Table 14). Strategies utilizing reverse auctions may be more successful at achieving conservation here than they would be in other areas. The species in the Southern Region are typically non-mobile, limiting the usage of off-site mitigation; however, the highly mobile species of Cluster 1 provide an exception to this.

TABLE 14: Trait Clusters for Southern Region Species

	Cluster 1	**Cluster 2**	**Cluster 3**	**Cluster 4**
Species	*E. boehlkei* [Fish]; *P. bulenta* [Butterfly]	*L. fullerkati* [Mussel]	*P. magnifica* [Snail]	*F. masoni* [Mussel]; *T. pullus* [Mussel]
Endemism	High	Very High	Very High	Low to Moderate
Habitat Specificity	Narrow to Moderate	Broad	Narrow	Narrow to Moderate
Mobility	High	Non-Mobile	Low	Non-Mobile
Migratory Behavior	No	No	No	No
Interspecific Associations	Variable	Yes	Yes	Yes
Habitat Variability Through Life Cycle	Variable	No	No	No

CHAPTER 5: DISCUSSION

MOUNTAIN REGION

Retrofitting dams is a potentially ideal mitigation technique to use in the Mountain Region. Dam retrofits could allow passage of the region's lone migratory species, *Moxostoma sp. 2* (sicklefin redhorse). Retrofits also normalize stream flow conditions. Long term payments to dam operators, perhaps in the form of conservation easements, can incentivize this mitigation. (Ongoing payments may be required due to the partial loss in dam functionality associated with the retrofits). The use of reverse auctions to identify participating dam operators is somewhat limited by the habitat specificity of the region's species.

Several of the species have strong interspecific associations, most notably the freshwater mussels. Any conservation agreement targeting these species should also focus on the viability of these associate species. Most of the target species within the region have low mobility, restricting the use of off-site habitat restoration. Off-site restoration has the potential to conserve other species in the region that were not considered by this analysis.

Demand for pre-compliance conservation in this region may be legal or political. Federal agencies own a large portion of the land in this area (Figure 4). These agencies are under political pressure, from both outside and inside the government, to promote environmental stewardship. For example the Council on Environmental Quality, in accordance with Executive Order 13514, has issued a guidance document directing federal agencies to incorporate ecosystem services into their programs and projects (Council on

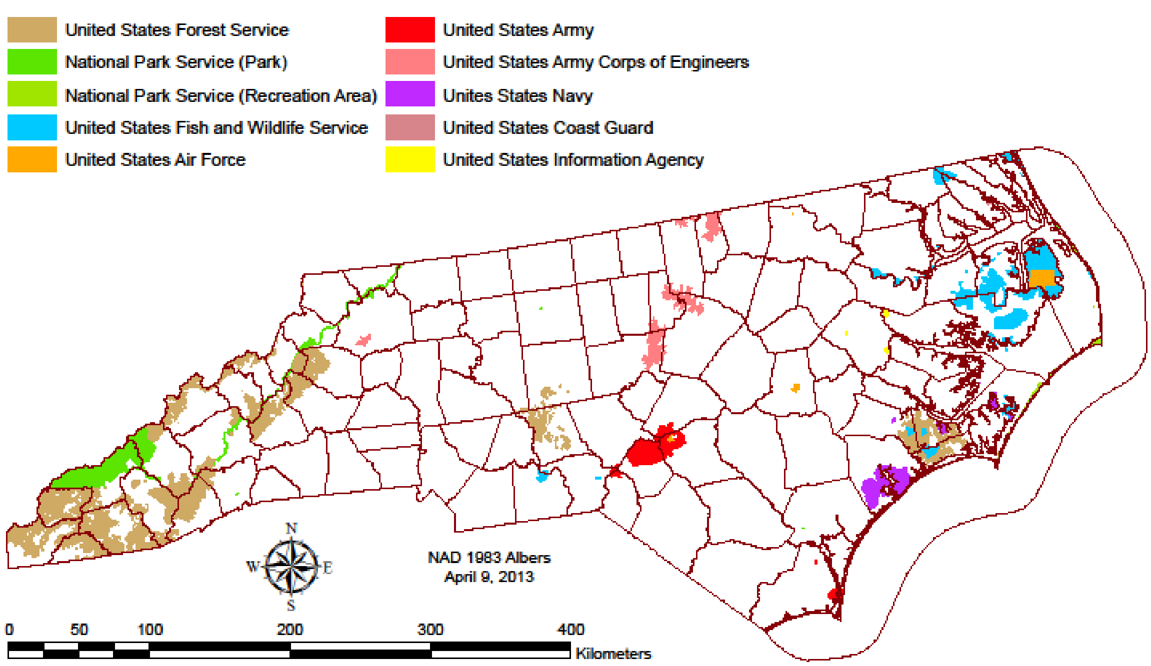

Figure 4: Federal Land Ownership in North Carolina

Environmental Quality 2011). Agencies such as the Forest Service or the National Park Service could incorporate pre-compliance conservation goals into the NEPA (National Environmental Policy Act) process. While preparing environmental impact statements, the agency could consider its impacts on imperiled yet unprotected species; conservation managers could then work with the agency to mitigate these impacts and preserve essential ecosystem services.

CENTRAL REGION

With the variety of stressors facing the Central Region species, there are several mitigation techniques that might need to be employed to conserve these species effectively. Without more information, it may not be possible to identify a single best strategy for the region.

Riparian buffers can limit runoff, reintroduce woody debris to aquatic habitats, and reduce water temperatures. Assurances of "No Additional Restrictions" (NAR) beyond those agreed to in the conservation agreement can incentivize landowners to establish buffers, as can one-time direct payments. Adopting best management practices (BMP) can decrease pollution. The ongoing efforts to adopt BMP may require continual payments (which can come in the form of conservation easements) or an assurance that the landowner can return habitat to a baseline quality (BHQ) at the end of an agreement period.

Modifications to existing development, such as increased surface permeability, can reduce runoff. With the permanent nature of these protections, incentives can be provided through NAR assurances or one-time payments. Retrofitting dams is similar to modifying development; due to reduced dam functionality, however, long term payments to dam operators (such as conservation easements) may need to be provided as incentives.

Increased water temperatures can be reduced with artificial shade covers. Due to the permanent nature of these protections, incentives might be provided through NAR assurances or one-time payments. Erosion and sedimentation along roadsides can be prevented through erosion control measures such as wire netting or native vegetation. Incentives for erosion control can be provided through BHQ assurances or continual payments (perhaps in the form of conservation easements). Targeted invasive species removal could also be incentivized by BHQ assurances or conservation easements. Due to the generally low mobility of the region's species, all three of these techniques would need to be conducted on-site, precluding a conservation exchange market.

On-site stream restoration can mitigate some of the habitat degradation associated with development. Incentives for habitat restoration can be provided through BHQ assurances or continual payments (perhaps in the form of conservation easements). Most of the target species within the region have low mobility, restricting the use of off-site habitat restoration. Off-site restoration has the potential to conserve other species in the region that were not considered by this analysis.

Most of the species within the Central Region have strong interspecific associations; any conservation agreement targeting these species should also focus on the viability of these associate species. The use of reverse auctions to identify participating landowners is somewhat limited by the habitat specificity of the region's species.

The desire to avoid regulatory restrictions that could hamper future development is likely a primary motivation for landowners in this region. Development can be threatened by the presence of species that may be protected in the near future. An example of this can be seen in Raleigh, where developers are considering damming the Little River to establish a new reservoir. The proposed project has raised several environmental concerns, however, including its impacts on species being considered for federal protection (Riechers 2012). In response to these concerns, developers may be willing to enter into flexible pre-compliance agreements to avoid strict restrictions following a potential species listing.

EASTERN REGION

In the Eastern Region, establishing riparian buffers can limit agricultural runoff. Improvements to technology and infrastructure can also improve efficiency and reduce the over usage of water. Due to the permanent nature of these protections, incentives might be provided through NAR assurances or one-time payments.

The adoption of best management practices (BMP) could alleviate a variety of agricultural threats within the region, including fertilizer and sediment runoff, soil erosion, and water overuse. These protections are temporary in nature; continual payments (perhaps in the form of conservation easements) or BHQ assurances that allow farmers to revert to previous practices could provide incentive to improve their practices.

Most of the species within the Central Region have strong interspecific associations; any conservation agreement targeting these species should also focus on the viability of these associate species. The use of reverse auctions to identify participating landowners is somewhat limited by the habitat specificity of the region's species. Most of the target species within the region have low mobility, restricting the use of off-site habitat restoration. Off-site restoration has the potential to conserve other species in the region that were not considered by this analysis.

Several factors may create landowner demand for pre-compliance conservation in this region. Fear of land use restrictions may motivate farmers to take conservation measures to avoid future regulations. While non-mobile species limit the use of off-site habitat restoration in the area, the water needs of downstream landowners present opportunities to trade ecosystem services. Farmers can also receive compensation for voluntary conservation measures through farm bill conservation programs (see discussion below).

SOUTHERN REGION

Riparian buffers can limit siltation and runoff, can reintroduce woody debris into aquatic habitats, and can reduce stream temperatures. NAR assurances or one-time payments might incentivize landowners to establish buffers. Given the ability of riparian buffers to address a variety of deforestation related impacts, this may be the ideal strategy to employ in this region.

On-site stream restoration can reintroduce woody debris. Restoration requires long term efforts on the part of landowners; therefore, BHQ assurances or long term payments (perhaps in the form of conservation easements) might be required as incentives. Artificial stream shades can reduce water temperatures by replacing some of the lost canopy cover. Incentives might be provided through NAR assurances or one-time payments.

Most of the species within the Central Region have strong interspecific associations; any conservation agreement targeting these species should also focus on the viability of these associate species. While some of the species of this region are habitat specialists, there are also several generalists; reverse auctions could therefore be used in this region.

Compared to the other three regions, the source of demand for pre-compliance action are less clear in the Southern Region. There is some agriculture in this area, so landowners may face similar motivations to those of the Eastern Region. Wetlands comprise a large portion of this region; section 404 of the Clean Water Act (CWA) requires wetland mitigation in response to certain agricultural activities (CWA 33 U.S.C. § 1344, EPA 2012). Given the limited mobility of many of the region's species, any wetland mitigation efforts would need to be strictly regulated.

IMPLEMENTING PRE-COMPLIANCE AGREEMENTS

Pre-compliance conservation agreements can be implemented in many ways, and there are many resources that landowners and conservation managers can use in their implementation. One prominent example is Section 319 of CWA. This section provides resources that allow farmers to reduce their NPS runoff (CWA 33 U.S.C. § 1339, EPA 2005).

The U.S. farm bill is updated every five years and oversees a variety of agricultural affairs. The bill includes a variety of conservation programs operated by the Natural Resources Conservation Service. These programs provide farmers, ranchers, and other landowners resources to help mitigate their environmental impacts. They are typically operated on a voluntary basis and are open to landowners who wish to participate (NRCS 2013).

There are many different farm bill conservation programs; each details several ways farmers may reduce their impacts, including erosion control, water quality preservation, or habitat restoration (NRCS 2013). Programs such as the National Water Quality Initiative or Agricultural Water Enhancement Program provide farmers financial compensation to improve management practices, conduct erosion control, and establish riparian buffering, all with the aim of preventing runoff of nutrients and livestock waste. The Conservation of Private Grazing Land initiative provides technical assistance to improve management practices and reduce soil erosion. The Wildlife Habitat Incentive Program provides a combination of technical assistance and financial cost-sharing to landowners voluntarily restoring or conserving habitat for at-risk species. The Wetland Reserve Program provides landowners with the resources to conserve and restore wetlands on their property, and offers the option of entering into a 30 year conservation easement. Many of these programs can be coordinated through non-governmental organizations (NRCS 2013).

Chapter 6: Conclusion and Future Applications

This project hopes to provide the Environmental Defense Fund with a tool to aid their decision-making and spend their resources effectively as they pursue pre-compliance conservation in North Carolina. This analysis identified the best pre-compliance mitigation strategies to employ in four geographic regions (Figure 5). In the Mountain Region, the best strategy involves retrofitting dams to naturalize stream flow. In the Southern Region, the best strategy involves establishing riparian buffers to mitigate the effects of deforestation. Three ideal strategies were identified in the Eastern Region: establishing riparian buffers, adopting BMP, and improving technology and infrastructure. In the Central Region, there are a large number of potentially useful strategies that might be employed.

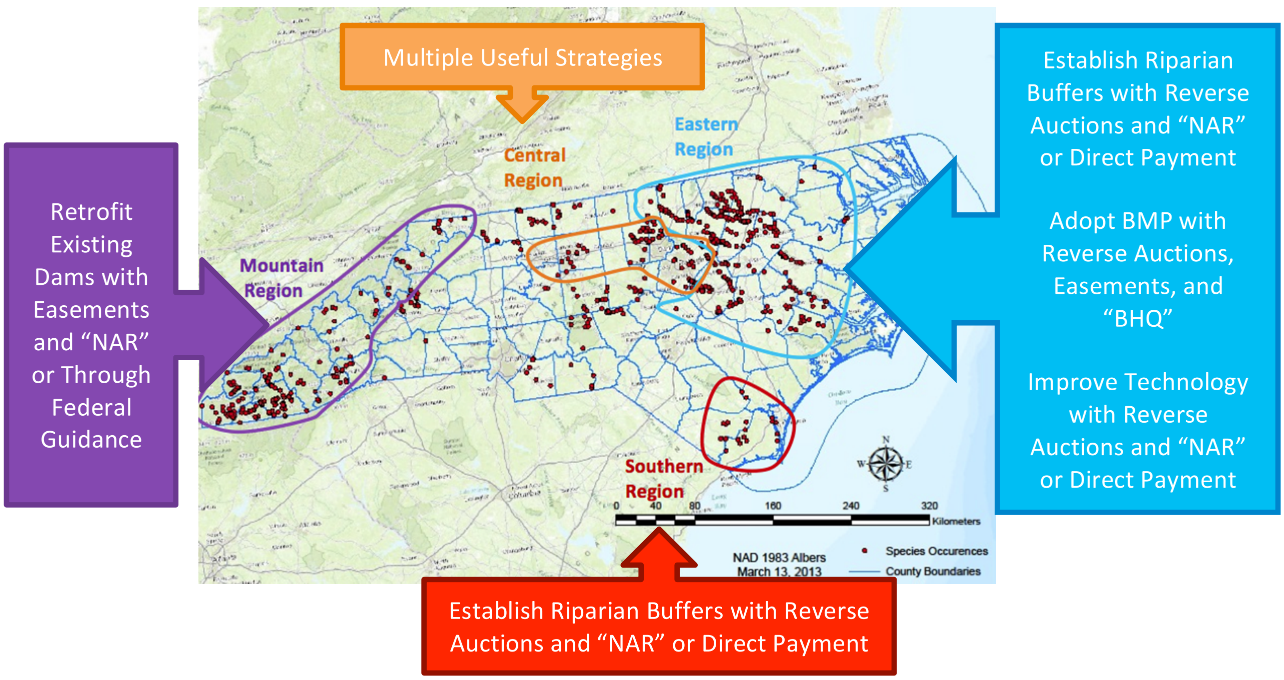

Figure 5: Best Mitigation Strategies and Policy Tools by Geographic Region

RECOMMENDATIONS

I recommend that a priority be placed on the Mountain Region. This area has a large number of species, and also has relatively little overlap with the other regions in terms of species composition; that is, this region encompasses the extent of many species' North Carolina range. The large amount of federal land in the region might also make it easier to find cooperating partners committed to restoring ecosystem services.

I would next prioritize the Southern Region. While there is not a large number of species here in total, this region is home to the greatest number of unique species after the Mountain Region. There is also a single mitigation strategy within this region with the potential to address a variety of ecological impacts. Furthermore, the large amount of wetlands in this region may make it necessary for landowners to comply with section 404 of CWA.

There is a large degree of overlap in the species composition between the Eastern and Central Regions. I recommend a higher priority be given to the Eastern Region, as the smaller variety of threats within this region might make it easier to develop an effective conservation strategy. Furthermore, the farm bill conservation programs provide excellent opportunities for farmers to be compensated for voluntary conservation efforts.

Appendix I: Spatial Threats By Region

TABLE 15: Mean Spatial Proximity of Threats in Mountain Region

Species	Agricultural Density (5 km)	Development Density (5 km)	Forest Cover Density (5 km)	Road Density (5 km)	Dam Index (see below)
Cambarus chaugaensis	0.010569833	0.065741433	0.905718667	0.163466	0.971176896
Cambarus georgiae	0.105526024	0.078089628	0.77532652	0.153801343	0.530599635
Cambarus parrishi	0.05912428417	0.03518159167	0.87875316667	0.0587418250	0.15036076611
Cryptobranchus alleganiensis	0.111235402	0.078797302	0.778693217	0.201600607	0.61096778
Desmognathus aeneus	0.010497745	0.021053403	0.934243238	0.057807771	0.215532321
Fusconaia subrotunda	0.1528165	0.08270075	0.728617	0.0977365	0.977842505
Lasmigona holstonia	0.242855167	0.100416733	0.625105333	0.211594	0.970046525
Lasmigona subviridis	0.184787833	0.052175117	0.729429667	0.151632433	0.6259005
Macromia margarita	0.1025115	0.06781005	0.815741	0.10390795	0.476064487
Megaleuctra williamsae	0	0.0316522	0.966258	0.235609	0
Moxostoma sp. 2	0.07095616556	0.08364370000	0.76698244444	0.1572228333	0.79323613956
Ophiogomphus edmundo	0.00757948	0.0179328	0.965801	0.0895435	0.824528041
Pleurobema oviforme	0.135832967	0.1025701	0.711896333	0.142968	0.934729345
Pleuronaia gibberum	0.079282857	0.060816814	0.815014	0.194769857	0.890954792

TABLE 16: Mean Spatial Proximity of Threats in Central Region

Species	Agricultural Density (5 km)	Development Density (5 km)	Forest Cover Density (5 km)	Road Density (5 km)	Dam Index (see below)
Alasmidonta varicosa	0.16286175	0.10763655	0.6668395	0.1679055	0
Cambarus catagius	0.093062548	0.641692917	0.224905308	0.401581833	0.243877385
Elliptio lanceolata	0.24312250000	0.16815825000	0.37227875000	0.3651975	0.96984528543
Fusconaia masoni	0.222457853	0.141019616	0.521565789	0.236154297	0.882074821
Gomphus septima	0.0341533	0.493659	0.433891	0.277837	0.963363374
Lasmigona subviridis	0.22682952	0.15780168	0.5050374	0.2791058	0.960675682
Necturus lewisi	0.152876521	0.243504963	0.470456875	0.230405383	0.965324485
Noturus furiosus	0.073269225	0.53004375	0.275344	0.31745	0.975888237
Toxolasma pullus	0.0882141	0.307414	0.570515	0.273938	0.97025095383

TABLE 17: Mean Spatial Proximity of Threats in Eastern Region

Species	Agricultural Density (5 km)	Development Density (5 km)	Forest Cover Density (5 km)	Road Density (5 km)	Dam Index (see below)
Alasmidonta varicosa	0.19710625	0.046176	0.62106025	0.21845625	0.48332088
Elliptio lanceolata	0.26069711192	0.08037515695	0.44975150331	0.1982253159	0.90323993072
Fusconaia masoni	0.261298238	0.074149328	0.465847989	0.189682951	0.866778766
Lasmigona subviridis	0.239396667	0.154308878	0.412685778	0.283770833	0.843551314
Necturus lewisi	0.304345834	0.073979651	0.357619339	0.213013673	0.774194086
Noturus furiosus	0.325510822	0.08553624	0.28608712	0.223987624	0.84165725
Orconectes virginiensis	0.20689294286	0.05224215714	0.16576144286	0.1833462571	0.57098316270

TABLE 18: Mean Spatial Proximity of Threats in Southern Region

Species	Agricultural Density (5 km)	Development Density (5 km)	Forest Cover Density (5 km)	Road Density (5 km)	Dam Index (see below)
Elassoma boehlkei	0.06898071	0.018414099	0.330553167	0.050567639	0.223516062
Fusconaia masoni	0.1277094	0.01976485	0.3361565	0.218484	0.436328515
*Lampsilis fullerkati**	0.12835	0.066662	0.576689	0.259859	0.397894713
Planorbella magnifica	0.02803988	0.251431033	0.278382767	0.261762	0.303474649
Problema bulenta	0.01874325	0.307899	0.08646195	0.414406	0
*Toxolasma pullus**	0.12835	0.066662	0.576689	0.259859	0.39789471281

*=The EO points within the Southern Region for these two species occurred in the same lake. Threat densities for these two species are based on the approximate area 5 km beyond the edge of the lake.

The "Dam Index" was derived by considering the distance to the nearest upstream dam, within 100 rkm. If a dam was within 100 rkm upstream of a population, the population was given a scores of:

$$\frac{100 - [Upstream\ Distance\ in\ rkm]}{100}$$

If no upstream dam was identified for that population, or if the nearest dam was more than 100 rkm upstream, that population was given a score of 0. In each region, a species population scores were averaged to give the species a Dam Index score for the region. Higher scores represent a higher threat from river impoundment.

APPENDIX II: SPECIES LIFE HISTORY TRAITS

TABLE 19: Ecological Life History Trait Matrix

Species	Watersheds Occurred In	Habitat Specificity	Mobility (meters)	Migratory	Interspecific Associations	Habitat Variation
Alasmidonta varicosa	91	Narrow	1	No	Larval hosts: *Rhinichthys insignis*, *Perca flavescens*, *Rhinichthys atratulus*, *Cottus cognatus*	None
Cambarus catagius	3	Moderate	10	No	None	None
Cambarus chaugaensis	2	Narrow	100	No	None	None
Cambarus georgiae	2	Narrow to Moderate	10	No	None	None
Cambarus parrishi	3	Narrow	10	No	None	None
Cambarus spicatus	1	Moderate	100	No	None	None
Cryptobranchus alleganiensis	123	Very Narrow	10	No	None	None
Desmognathus aeneus	14	Narrow to Moderate	10	No	None	None
Elassoma boehlkei	6	Moderate	1000	No	None	None
Elliptio lanceolata	45	Narrow to Moderate	1	No	Larval hosts: unknown	None
Fusconaia masoni	44	Narrow	1	No	Larval hosts: *Lepomis cyanellus* and *Percina peltata*	None
Fusconaia subrotunda	89	Narrow	1	No	Larval hosts: unknown	None
Gomphus septima	10	Narrow	100	No	None	Yes
Lampsilis fullerkati	1	Broad	1	No	Larval hosts: unknown	None
Lasmigona holstonia	22	Broad	1	No	Larval hosts: *Cottus carolinae*, *Ambloplites rupestris*	None
Lasmigona subviridis	74	Moderate	1	No	Larval hosts: unknown	None
Macromia margarita	7	Narrow to Moderate	1000	No	None	Yes
Megaleuctra williamsae	3	Narrow	1000	No	None	Yes
Moxostoma robustum	17	Narrow	100000	Yes	None	Yes
Moxostoma sp. 2	3	Narrow	100000	Yes	Food source: *Podostemum ceratophyllum* (promotes abundance of prey species)	Yes
Necturus lewisi	7	Very Narrow to Narrow	10	No	None	None
Noturus furiosus	7	Narrow	1	No	None	None
Noturus gilberti	4	Narrow	1	No	None	None
Ophiogomphus edmundo	2	Narrow	1000	No	None	Yes
Orconectes virginiensis	3	Moderate	10	No	None	None
Planorbella magnifica	1	Narrow	1	No	Habitat: *Niiphar liiteum*, *Nymphaea odorata*	None
Pleurobema oviforme	34	Narrow to Moderate	1	No	Larval hosts: *Campostoma anomalum*, *Nocomis micropogon*, *Notropis comutus*, *Cyprinella galacturus*, *Notropis leuciodus*, *Notropis telescopis*, *Etheostoma flbellare*	None
Pleuronaia gibberum	24	Moderate	1	No	Larval hosts: unknown	None
Problema bulenta	8	Narrow	1000	No	Food source: *Spartina cynosuroides* (as larva)	Yes
Toxolasma pullus	19	Moderate	1	No	Larval hosts: *Lepomis macrochirus*/*Lepomis cyanellus hybrid*	None

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