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The Human Dimensions and Spatial Ecology of Poaching and Implications for Red Wolf Survival

Suzanne Agan
Antioch New England Graduate School

ANTIOCH UNIVERSITY
NEW ENGLAND

Department of Environmental Studies

DISSERTATION COMMITTEE PAGE

The undersigned have examined the dissertation entitled:

THE HUMAN DIMENSIONS AND SPATIAL ECOLOGY OF POACHING AND IMPLICATIONS FOR RED WOLF SURVIVAL

Presented by Suzanne W. Agan
Candidate for the degree of Doctor of Philosophy, and hereby certify that it is accepted*

Committee Chair: Lisabeth L. Willey, Ph.D.
Professor, Department of Environmental Studies, Antioch University New England

Committee Member: Jimmy W. Karlan, EdD
Professor, Department of Environmental Studies, Antioch University New England

Committee Member: Adrian Treves, Ph.D.
Professor, Carnivore Coexistence Lab, University of Wisconsin-Madison

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*Signatures are on file with the Registrar's Office at Antioch University New England

THE HUMAN DIMENSIONS AND SPATIAL ECOLOGY OF POACHING AND IMPLICATIONS FOR RED WOLF SURVIVAL

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Suzanne W. Agan

ORCID Scholar No. 0000-0002-3672-3011

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ABSTRACT

THE HUMAN DIMENSIONS AND SPATIAL ECOLOGY OF POACHING AND IMPLICATIONS FOR RED WOLF SURVIVAL

Suzanne W. Agan

Antioch University New England

Keene, New Hampshire

In the 1970's, red wolves were considered America's most endangered mammalian species and the US Fish and Wildlife Service (USFWS) developed the Red Wolf Recovery Plan soon after passage of the Endangered Species Act (ESA) to preserve and eventually reintroduce them. It marked the first successful attempt to reintroduce a large predator that had been completely extirpated from the wild. The conservation of predators, such as red wolves, stirs controversy when it hinders human activities and some people retaliate by illegal killing. In Northeastern North Carolina (NENC), poaching has been a problem throughout the entire recovery process and is the leading cause of death in this endangered wild population. Understanding the behaviors and attitudes of poachers, and other factors related to the illegal killing of red wolves, is critical to successful recovery of this endangered species. The overall goal of this interdisciplinary research, drawing on the fields of conservation biology, social psychology, geographic information systems, and wildlife management was to explore poaching risk, how attitudes contribute to poaching decisions, and then how social factors, along with ecological factors contribute to increased risk of red wolves being poached, reducing population viability. We found that poaching is responsible for more deaths than any other cause, and in particular those wolves that disappear need to be included in risk estimates. Our interviews and surveys revealed the amount of complexity involved in both attitudes and behavioral inclination with a majority of respondents showing positive attitudes toward both red wolves and their conservation and those who dislike them are in a small minority. Spatial analysis results suggest human-wolf interactions are spatially associated with landscape characteristics that are appealing to both species and that social variables such as behavioral inclination can strengthen the predictive power of models describing those interactions. Using research that considers both environmental and social variables such as ours can provide guidance for conservation and management interventions. Implementing proven practices that prevent poaching or hasten successful reintroduction can reverse the trend of a decreasing NENC red wolf population and once again allow red wolves to thrive, not only in NENC but additional future reintroduction sites. This dissertation is available in open access at the Antioch University Repository and Archive (AURA), http://aura.antioch.edu and OhioLINK ETD Center, https://etd.ohiolink.edu.

Keywords: red wolves, spatial analysis, poaching, mortality risk

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Chapter 1: Introduction

Predators have always stirred dramatic reactions from humanity. They have been objects of fear in children's stories such as the Big Bad Wolf or of inspiration as in the Lion King. In reality, apex predators are a vital part of the ecosystems in which they live. Usually large predators, known as apex predators, occupy the top trophic (feeding) position in a community, and provide structure, function and stability to those ecosystems (Berger, Gese, & Berger, 2008; Prugh et al., 2009; Ritchie & Johnson, 2009). They do this through top-down influence on multi-link food web interactions by having significant effects on herbivores, which then influence vegetation, a process also known as a trophic cascade (Berger et al., 2008; Ripple & Beschta, 2005). Apex predators also suppress smaller predators, known as mesopredators, and can moderate their impact on even smaller prey species (Prugh et al., 2009). In a study done by Berger et al. (2008), areas used by wolves in the Greater Yellowstone Ecosystem were associated with lower numbers of transient coyotes and a four-fold higher survival rate of pronghorn fawns. That same study discussed how the loss of wolves and grizzly bears resulted in trophic cascades involving increased moose numbers, decreased willow abundance and decreased diversity of neotropical songbirds (Berger et al., 2008).

Through the ecological sciences, we now understand importance of predator species, but that was not always the case. In 1915, the fate of wolves in the United States (US) was sealed when Congress authorized the Bureau of Biological Survey to eliminate the remaining wolves in the US. Despite recognizing a public trust doctrine (Sax, 1970) in which environmental components, including wildlife, are held in trust for future generations, wolves were eradicated across the US, in part due to government sponsored programs (Treves et al., 2015). Wolves were functionally extirpated by the 1930's and ungulate population irruptions began immediately after

(Ripple & Beschta, 2005). It was during this time that conservationist Aldo Leopold developed his hypothesis about the importance of predators. He describes his views on the top-down management provided by wolves and other apex predators in *A Sand County Almanac* (Leopold, 1970). We now know that wolves influence ecosystem processes through both lethal (depredation) and nonlethal (behavioral) affects. Wolves are also crucial for the maintenance of biodiversity through improved nutrient cycling, food web support for scavengers, and as a buffer against invasive species, disease transmission, and climate change (Ripple & Beschta, 2005; Ritchie et al., 2012).

The passage of the Endangered Species Act (ESA) of 1973 paved the way for reintroducing predators including gray wolves in the Northern Rockies and Upper-Midwest, Mexican wolves in the Southwest, and red wolves in the Southeast (Nie, 2001). The ESA is recognized as a powerful instrument to prevent extinction, by prioritizing preservation over development or economic activity, and has been credited with predator recoveries in the US (Treves et al., 2015). In the 1970's, red wolves were considered America's most endangered mammalian species and the USFWS developed the Red Wolf Recovery Plan soon after passage of the ESA to preserve and eventually reintroduce them (Carely, 2000). It marked the first successful attempt to reintroduce a large predator that had been completely extirpated from the wild (Hinton et al., 2013). The last remaining wild red wolves were captured, a captive breeding program was implemented and red wolves were reintroduced into Northeastern North Carolina (NENC) beginning in 1987 (Bartel & Rabon, 2013).

The conservation of predators, such as red wolves, stirs controversy when it hinders human activities. Some people retaliate by illegal killing of the protected carnivores and in NENC, poaching has been a problem throughout the entire recovery process. Landowners there believed the endangered status would interfere with their land use, while special advocacy groups believed new policy would not give them enough protection (Gilbreath & Henry, 1998). That difficulty was addressed before reintroduction by classifying wild red wolves in NC as a nonessential experimental population, giving the USFWS more flexibility in working with landowners. Through this designation, the killing of a wolf would be allowed in situations such as threat to human safety, and harassment or removal of wolves for landowners in other situations (Gilbreath & Henry, 1998). With an underlying distrust of government policy, residents still feared the designation would be changed to endangered once wolves were present on their property, and restrictions would be placed on the use of their land.

Currently, anthropogenic mortality is the leading cause of deaths in the endangered red wolf population in NENC. Suspected illegal killing, including gunshot, poisoning, and trapping, accounted for 30% of all mortalities between the years of 1987 and 2012 (Bartel & Rabon, 2013). Unpublished USFWS data from 1987 – 2012 showed a slightly different percentage. It includes 353 deaths with 40% mortality from illegal killing (94 gunshot, 10 poison, 26 trapping, and 8 listed as foul play). Gunshot mortality increases 7.2 times during deer hunting season when compared to the rest of year, and a higher percentage of wolves that go missing are unrecovered during this same time (Hinton et al., 2015). Mortality rates are also greatest for red wolves less than 4 years old, perhaps due to inexperience with human activities, making them more vulnerable to opportunistic killing by hunters (Hinton et al., 2016). When wolves are killed during breeding season, hybridization rates increase with coyotes since losing a mate during this time increases the chance a wolf will breed with a coyote rather than not at all (Hinton et al., 2015). Ultimately, anthropogenic mortality reduces the possibility of a self-sustaining population, the goal of the Recovery Plan, and could ultimately cause the extinction of the species in the absence of intervention (Hinton et al., 2013).

Anthropogenic mortality can have additive effects on red wolf populations at low densities since killing breeding individuals can disrupt pack dynamics, reduce numbers of litters, and decrease genetic purity through increased hybridization with coyotes (Hinton et al., 2016; Sparkman et al., 2011). While minimum viable populations are difficult to determine, and no such estimate has been made for red wolves in NENC, both Hinton et al. (2016) and Murray et al. (2015) agree that current conditions are inadequate to establish a viable self-sustaining population. If poaching continues in the red wolf population, we could soon witness yet another human caused extirpation of wild red wolves.

Understanding the behaviors and attitudes of poachers, and other factors related to the illegal killing of red wolves, is critical to successful recovery of endangered species. Treves et al. (2013) predicted future increases in legal and illegal killing of gray wolves would reduce their abundance unless interventions were taken to improve attitudes and behaviors. Scientists know more about motivations to poach than the attitudes and behavior underlying poaching. While motivations such as commercial gain and thrill killing have been extensively documented and even empirically tested, the reliability of social science research on poaching is complicated by concealment of the activity (Treves et al., 2017). Attitudes are also harder to define as they are usually very complex and can change. Recent research has begun using social psychology and criminology theories to explore these attitudes such as rational choice theory, routine activity theory, and the theory of planned behavior (Treves et al., 2017). Attitude can be used as a predictor of behavior such as poaching and so these studies are important to learn how attitudes can develop and change over time and the drivers of those changes. In a longitudinal study of gray wolves, residents living in wolf range became less tolerant of wolves over time due to increased fear of wolves and competition for deer. Survey results also showed an increase in the inclination to poach wolves (Treves, Naughton-Treves, & Shelley, 2013). The results of Treves et al. (2013) cast doubt on the strength of personal experience with wolves in changing attitudes, but other studies have shown experience with wolves to either increase or decrease negative attitudes toward them (Ericsson & Heberlein, 2003; Kellert, 1985). This diversity in results shows the importance of context in studies. No such attitude research has been conducted in NENC since red wolves were reintroduced over thirty years ago and determining what those attitudes are and how they have developed can help determine poaching behaviors in that context (Treves et al., 2013).

In NENC, the current red wolf population is only approximately 45-60 individuals (US Fish & Wildlife Service, n.d.). They are listed as critically endangered on the IUCN Redlist and their wild population has been declining since reaching its maximum NENC recovery population of an estimated 151 individuals in 2005 – 2006 (Hinton et al., 2016). In NENC, reintroduction efforts were suspended in June 2015 pending examination of the recovery program. Since then efforts have been limited to only managing the current population until the five-year review and new policy recommendations are released. The five-year review was released April 24, 2018 and the new policy was expected late summer 2018 (US Fish & Wildlife Service, n.d.), however there has been no decision by the USFWS at the time of this writing. As described above, research has shed light on the ecological importance of wolves in general, and we know what happens ecologically when red wolves are killed. There is also a lot of research on attitudes and behavior as discussed here. However, there is no research on how attitudes in NENC combine with other factors to determine poaching behaviors and the resulting risk to red wolves.

Research Approach

The overall goal of this interdisciplinary research, drawing on the fields of conservation biology, social psychology, geographic information systems, and wildlife management is to explore how attitudes contribute to poaching decisions, and then how social factors of attitude and acceptance, along with ecological factors contribute to increased risk of red wolves being poached, reducing population viability.

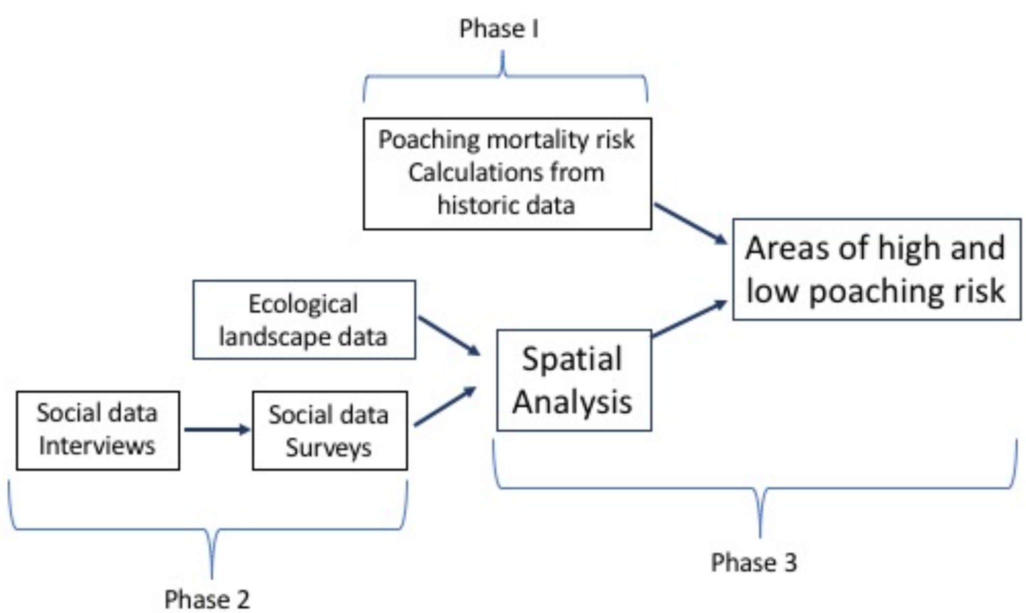

Fig 1. Conceptual framework

My research was carried out in three stages (Fig 1). First, the goal of chapter two was to calculate poaching mortality risk in the red wolf population using USFWS historical data and “fate unknowns” which have been excluded in past publications. Fate unknown refers to wolves for which radio signal has been lost and their fate is unknown to the USFWS. Second, in chapter three, through semi-structured interviews with NC residents, the goal was to better understand attitude characteristics and behavioral inclinations of residents in NENC. I also hope to identify those factors that limit poaching, reasons for which people will not kill a red wolf when presented with the opportunity. Since gunshot mortality increases during hunting season, I focused on the hunting community including hunters and hunting lease landowners. In addition to interviews, I also conducted an Internet survey for the five-county red wolf recovery area and surrounding counties to better understand overall attitudes for the area. The results of this survey were used to create an attitude layer for the last phase of my research. Finally, in chapter four, my goal was to conduct a spatial analysis of the vulnerability of poaching of red wolves in NENC that combines ecological and social risk factors in order to inform future management efforts.

Research Questions

Chapter 2: What is the risk for different types of mortality in the wild NENC red wolf population?

- What is mortality risk for 5 types of mortality (legal, poached, vehicle, nonhuman, and unknown) in the red wolf population from 1987 – 2018?
- How does mortality risk vary between hunting and nonhunting season?
- How does “time/age to disappearance” for fate unknowns compare to “time/age of death” for different types of mortality?

Chapter 3: What are landowners’ attitudes and behavioral inclinations toward red wolves and their protection?

- How do the roles of landowner, hunter, and resident correlate with their attitude toward red wolves and what are the differences between these groups and their counterparts?
- What is the correlation between attitude toward red wolves, social norms relating to their protection, opportunity to encounter red wolves, and intention to kill them?

- How does Routine Activity Theory (RAT) and recent ideas on opportunity relate to poaching for both would-be poachers and those without the intention to kill a red wolf?
- What is the relationship between attitude toward red wolves, support for their conservation, trust for the US Fish and Wildlife Service (USFWS) and attitude toward current policy?

Chapter 4: Combining data from chapters three and four, where are red wolves most vulnerable to poaching in the NENC red wolf recovery area?

- Does attitude toward red wolves, acceptance for the red wolf reintroduction program, and behavioral inclination correlate with documented poaching events?
- Where do local residents perceive red wolves to be at risk of being poached?
- How are the environmental variables of land cover, distance to public managed lands, distance to roads, deer density, and human population density associated with poaching risk?
- How do poaching locations change across the landscape during hunting season?

As the USFWS continues to manage this population in NENC and also seek out new reintroduction sites in the southeastern US, they will continue to face the issue of poaching. My research is designed to provide benefits to the current population of wild red wolves in NENC as well as possible future reintroductions. By using a risk model that includes social as well as ecological factors, managers can make more informed decisions in a local context. When managers are aware of where red wolves are most at risk of being poached, they can concentrate limited resources to those sites and situations or choose to reintroduce elsewhere. Better understanding of how poaching decisions develop, and how risk is assessed in the process, can facilitate good working relationships between stakeholders throughout the entire process from policy creation to population management.

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Chapter 2: Red wolf *Canis rufus* poaching risk in northeastern North Carolina

Suzanne Agan

Antioch University New England

Abstract

The reintroduced red wolf population in northeastern North Carolina (NENC) has been declining over the last 12 years to a low of only 19 wolves in 2018. Poaching (illegal killing) is a major component of anthropogenic mortality in this and many other carnivore populations, but it is still not well understood, disrupts management efforts, and is often underestimated. This underestimation is partly the result of cryptic poaching, when poachers conceal evidence, and it inhibits our understanding of the socioecological consequences. Understanding anthropogenic mortality is important to conservation as it can inform us about future population patterns within changing political and human landscapes. We estimate risk for 5 causes of death (legal, nonhuman, unknown, vehicle and poached) and disappearance accounting for all 508 marked adult red wolves, describe variation in mortality risk in relation to hunting season, and compare time until disappearance or death for collared adults. While traditional methods use known fate models, we include unknown fates in our risk estimates. We also investigated bias in cryptic poaching research to evaluate whether there were inaccuracies in official estimates. We found that anthropogenic causes of death are responsible for 0.724 – 0.787 of all red wolf deaths with poaching, including cryptic, at 0.510 – 0.635. Mean time to death for poached red wolves averaged 376 days less than those which died of nonhuman causes and time to disappearances averaged 642 days less than nonhuman COD. Our results for risk of various causes of death, when compared to previous published estimates, support the need for including unknown fates in risk estimates. Implementing proven practices that prevent poaching or hasten successful reintroduction can reverse the trend of a decreasing NENC red wolf population. Our findings add to a growing literature on endangered species protections and enhancing the science used to measure poaching worldwide.

Introduction

Carnivores play a significant role in the function of ecosystems as keystone species through top-down regulation, resulting in increased biodiversity across trophic levels [1–4]. They do this by influencing prey populations through predation or behavioral changes, creating a ripple effect, which can then create competition between prey species, forcing specialization and increasing fitness [1]. They also influence smaller predator populations, which again has effects on smaller prey species. In California, the absence of coyotes, a top predator in that ecosystem, behaviorally released opossums, foxes, and house cats which preyed heavily on song birds and decreased the number of species of scrub-dependent birds [1]. In Yellowstone, the return of wolves as a keystone species triggered top down effects that were wide-spread throughout the park and well documented [4]. If the presence of a top predator such as a wolf increases biodiversity and has positive effects on ecosystem function, then the absence of such carnivores can simplify biodiversity long-term and significantly impair ecosystem processes [1]. Under the Endangered Species Act (ESA) of 1973 the United States Fish and Wildlife Service (USFWS) is required to restore endangered species that have been eliminated, thereby restoring ecosystem function and increasing biodiversity [5]. Believed to have evolved only in North America, red wolves, *Canis rufus,* are an important part of US history and heritage [6], and they were one of the first carnivore species to be reintroduced under the ESA law. However, the reintroduced red wolf population in northeastern North Carolina (NENC) has been declining over the last 12 years to a low of only 19 wolves in 2018 (USFWS unpublished data). Until population stabilization occurs, natural and augmented expansion is important for small populations of carnivores like red wolves, to maintain genetic diversity, exclude competitors such as coyotes, and to facilitate metapopulation dynamics such as replacing lost breeding residents [7,8].

Anthropogenic mortality of carnivores

Even with legal protections, anthropogenic mortality is causing population decline in mammalian carnivores around the world [9]. Wolves are threatened by humans who dislike wolves (or their management), causing high rates of anthropogenic mortality and negatively influencing population growth [10]. In studying losses of Mexican wolves, *Canis lupus baileyi,* due to legal furbearer trapping in New Mexico, anthropogenic mortality accounted for 81% of all deaths [11]. Many studies show wolves have high levels of persecution [12–14], however the persistence of some carnivore populations in areas of high human density show human-carnivore coexistence is possible under the right conditions [15,16]. For example, Carter et al. (2012) found that tigers and humans co-existed even at small spatial scales, likely because tigers adjusted their activity due to human presence [16]. In North America, Linnel et al., found that carnivore populations increased after favorable policy was introduced, despite increases in human population density [17].

Poaching (illegal killing) is a major component of anthropogenic mortality in many carnivore populations [12,18,19], but it is still not well understood [13], disrupts management efforts [20], and is often underestimated [21]. This underestimation is partly the result of cryptic poaching, when poachers conceal evidence [9,13,14,20], and it inhibits our understanding of the socioecological consequences [9,13]. As a percent of all mortality, poaching accounts for 24 – 75% for different carnivore species and areas [22,23]. More than half of wolf mortalities in Scandinavia over the last decade are the result of poaching, with 69% of those having evidence concealed by the poacher [21]. In Wisconsin, poaching accounted for 39% - 45% of all wolf mortalities over a 32 year period with an estimated 50% cryptic, but this number is believed to be an underestimate because of non-reporting and uncertainty [12–14,21]. With very small populations and limited genetic diversity, the loss of even one wolf whose genes increase the fitness from a reproductively successful pack could affect recovery negatively [11] and thus reduce the possibility of population sustainability. The threat of poaching is becoming increasingly frequent in recovered populations, threatening these species with extinction, harming ecosystems, and depriving legitimate users of access to wolves [24].

Anthropogenic mortality decreases mean life expectancy for wolves, which has population wide effects. Living up to 10 years in the wild and 14 years in captivity [25], red wolves in NENC have an average of 3.2 years in the wild with breeding pair duration of only 2 years [26]. This prevents the development of social structure and pack stability, a key factor in preventing hybridization with coyotes [26–28]. Theoretically, wild populations could compensate for anthropogenic mortality through decreases in natural mortality or increases in productivity [29]. However, these types of deaths can be additive or super-additive if poachers not only kill the individual wolf but also impact others in the population through such effects as the loss of a breeder or a lactating female. Such a loss would also result in the loss of offspring for that and future years. In NENC, human-caused mortalities accounted for 40.6% of all breeding pair disbandment's with gunshots alone accounting for 71.2% of those [30]. Since the mid-2000's natural replacement of those breeders has decreased by 30% [30]. When dominant males are killed, there can be an increase in offspring mortality through mate turnover [31]. This is only more prominent in small populations at low density such as red wolves in NENC. If there is a large portion of non-breeding adults in the remaining population there is potential for recovery since new breeding pairs could take up residence, however long-term compensation for anthropogenic mortality depends on survival of those adults [29].

Assessment of mortality using the most current and comprehensive data is critical to better understand how sources of mortality influence the red wolf population and is fundamental to management strategies [19,32]. The Red Wolf Species Survival Plan (RWSSP) and USFWS 5-year review both call for removal of threats that have the potential to bring about the extinction of red wolves [33,34]. Poaching is the biggest threat to the red wolf population, however this has not been adequately addressed [32].

Challenges in measuring risk

Measuring mortality risk, the proportion of all deaths attributable to a given cause, depends on many factors including the ability to monitor individual carnivores throughout the population. Following individuals with GPS or VHF technology is the standard method but can be costly, compromise animal welfare, and creates bias when the technology fails, or wolves move out of range [35]. Since poaching is illegal and enforced by federal law including the ESA, there is strong incentive to destroy evidence, including radio-collars, which limits the data available to researchers studying the effects of poaching on the population and creating bias in the data [14,22]. The possibility that some animals, which are unmonitored, are poached must be included in poaching estimates even though poaching cannot be verified. Problems such as these can be addressed with models that allow multiple sources of data to inform estimates of variables, including unobservable variables like cryptic poaching [21,36]. We define an event as cryptic poaching when the poacher destroys the evidence that results from killing an animal. Destruction of evidence is rarely, if ever, associated with nonhuman causes of death [12].

Most studies involving mortality data make assumptions that unknown fates resemble known fates [12]. For this study we define unknown fates as those animals that are radio-collared but become lost-to-contact and unmonitored. These assumptions are in error (bias) because legal killing of wolves is never represented in unknown fates. When wolves are legally killed, they are always included in known fates and in calculated mortality risk. Because of this, unknown fates will never resemble known fates. Also, cryptic poaching is not represented in known fates and so again the two fates cannot represent each other correctly. By accounting for all marked animals, *m* (unknown fates) + *n* (known fates), estimating unknown variables, and considering cryptic poaching, we extract more information for mortality risk [12] than traditional methods.

Treves et al. [12] tested the hypotheses that unknown fates cause important losses of information, which bias results, and that poaching is systematically underestimated when this data is omitted. They found that for every population of wolves in the United States, when they corrected estimates by removing legal killing from unknown fates, their estimates of poaching risk were higher than government estimates, which assumed known fates would be representative of unknown fates. For example, when estimates for relative risk from other human causes included unknown fates, government reported risk for red wolves was 0.26 – 0.40 (26 – 40%) lower than corrected estimates.

Status of red wolves in northeastern North Carolina

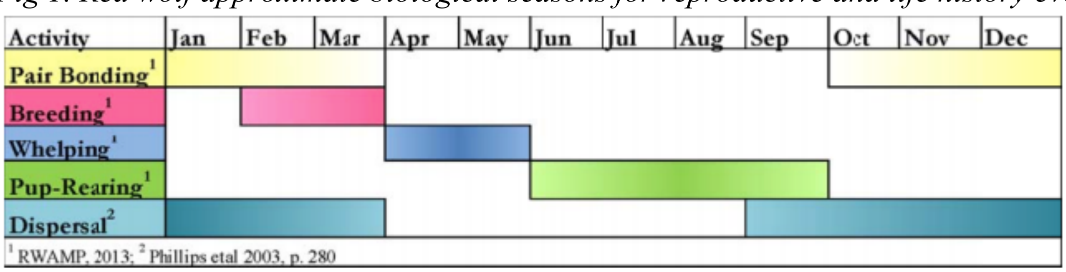
The history of red wolves in NENC is one of politically sanctioned killing just as it was in the rest of the United States, and these events were well-documented in local courthouse records [37], disproving the local notion that wolves have never existed in this area of North Carolina [37]. As one of the major actions in their recovery, the USFWS began a program to reintroduce red wolves into NENC in 1987, when four pairs of red wolves were first released into Alligator River National Wildlife Refuge [38]. Prior to this, county government and local sportsmen in NENC supported reintroduction as long as they could continue to hunt and trap in the same manner as hunting regulations had historically allowed [37]. That support has wavered however as coyote hunting regulations have changed since their migration east to NC during the 1990's [39].

Since its first reintroduction in 1987, US Federal legislation has not prohibited individuals from killing a red wolf in defense of life [37]. Then in 1995, to address private landowner concerns such as the fear of land use restrictions due to the presence of an endangered species, red wolves' designation changed to "experimental/nonessential", which further allowed harassment and/or take of wolves: 1) that are not intentional or willful, 2) that are directed at wolves in the act of killing livestock or pets, 3) after efforts by project personnel to capture unwanted animals have been abandoned, provided that the USFWS has approved such actions in writing [40]. It has been argued by researchers that over time, red wolf restoration has overrelaxed regulations by removing wolves for any reason when requested by a landowner or allowing the landowner to take (kill) the wolf after removal efforts fail [37]. However, the North American Model of Wildlife Conservation assumes wildlife is public property and not subject to removal unless there is a problem [41]. Managers have had to make difficult decisions between overrelaxing regulations and building support through the experimental designation (revised 1995 regulation) [37,42].

Currently, anthropogenic mortality is the leading cause of death for all wild red wolves in the endangered NENC population [32]. In the first 25 years of reintroduction, 72% of known mortalities were caused by humans, and in many cases avoidable. These included suspected illegal killing, vehicle strikes, and private trapping [38]. Gunshot mortalities alone increased by 375% in the years 2004 – 2012 compared to the 5 previous years [38] and increased 7.2 times during deer hunting season when compared to the rest of year. A higher percentage of wolves that go missing are unrecovered during this same time as opposed to outside hunting season [30].

Since red wolves were reintroduced, coyotes have migrated into eastern NC and have been subject to intense shooting and trapping control efforts by regulated hunting [30]. Shooting red wolves in this region is sometimes attributed to mistaken identity as a coyote and so efforts have been made to limit those occurrences of red wolf killing. Current NC state hunting regulations in the five-county red wolf recovery area (RWRA) restrict coyote hunting to daytime hours only and with a permit [43]. Other incidents of red wolf killing are intentional, and not a case of mistaken identity. Mortality rates are also greatest for red wolves less than 4 years old, perhaps due to inexperience with human activities, making them more vulnerable to opportunistic killing by hunters [32]. When wolves are killed during pair-bonding season (Fig 1), which coincides with hunting season, hybridization rates increase with coyotes since losing a mate during this time increases the chance a wolf will breed with a coyote rather than not at all [30]. Ultimately, anthropogenic mortality reduces the possibility of a self-sustaining population, the goal of the USFWS red wolf recovery plan, and could ultimately cause the extinction of the species in the absence of intervention [44].

Fig 1. Red wolf approximate biological seasons for reproductive and life history events [45].



Although there could be other factors affecting poaching numbers, there appears to be a correlation between poaching and political volatility [40], and evolving state policy has affected killing of red wolves. For example, North Carolina House Bill 2006, effective January 1, 1995, allowed landowners to use lethal means to take red wolves on their property in Hyde and

Washington counties in cases of defense of not only human life (as was always allowed) but also threat to livestock, provided the landowner had requested removal by the USFWS. After this policy was enacted, four wolves were shot over the course of Nov 1994 to Dec 1995 [40], the first known to be poached since reintroduction. Under policies more favorable toward wolves, such as those successfully carried out by the USFWS in Northern Rocky Mountains and Great Lakes populations, wolves have persisted [10]. However, it seems that both state and federal policy in NC have been less positive for red wolves and may partially explain why the population isn't thriving.

Research objectives and importance

Understanding anthropogenic mortality is important to conservation as it can inform future population patterns in changing political and human landscapes. The most recent red wolf population viability analysis (PVA), completed June 10, 2016 by the USFWS showed that mortality in breeding season has been increasing [8,30]. Results of the PVA estimate that without releases or improvements to vital rates, extinction of the NENC population will occur in 8 to 37 years. However, it could occur earlier because of the recent drop in population size from 74 known individuals since the starting point of the model [8] down to 19 known individuals as of 2018 (USFWS). There is the possibility of reduced probability of extinction, but only with reductions in mortality rates among other factors (releases and increased breeding rates). The red wolf PVA team calculated mortality rates using the midpoint values between the captive population in the Species Survival Plan (SSP), located throughout the US, and the NENC wild population [8]. This rate cannot be accurate since SSP populations don't experience poaching events. Also, levels of nonhuman deaths from interspecific and intraspecific competition would be much lower, if not zero, in the SSP populations since captive wolves are monitored and have much less interaction between packs and other species. Therefore, in order to accurately assess population viability, it is important to determine mortality rates using accurate historical data from only the wild red wolf population in NENC.

The five counties in the RWRA still have some of the lowest human densities in the state of NC, however human population is growing in these areas and the number of hunting licenses has continued to increase each year. Between 2011 and 2018, licenses increased 27% in Dare county, 20% in Beaufort, 11% in Hyde, 11% in Tyrell, and 8% in Washington [46]. Since gunshot mortalities of red wolves are higher during hunting season [30], additional hunters on the landscape could mean more opportunities for poaching.

The odds that we can prevent the population consisting of the last 19 red wolves from becoming extinct is considerably low. To establish the future viability of the red wolf population, it is important to determine current risk for different causes of death. We will investigate bias in cryptic poaching research to evaluate whether there are inaccuracies in official estimates. Treves et al. [12] tested the hypothesis that unknown fates of marked wolves cause important losses of information and also that poaching risk is currently underestimated and can be corrected when wolves with unknown fates are included. Their research tested this hypothesis for four wild wolf populations throughout the US including Northern Rocky Mountain gray wolves, *Canis lupus*, Wisconsin gray wolves, Mexican gray wolves, and red wolves. We will use those methods to test this same hypothesis for the NENC population of red wolves but including the most current red wolf statistics that add 11 years of data and a period of dramatic decline in the red wolf population. We will also analyze mortality risk around hunting season since poaching is so prevalent during this time.

There have been three previous papers which have studied anthropogenic mortality in the wild red wolf population (Sparkman et al., 2011, Murry et al., 2015, and Hinton et al., 2016) [29,32,47]. The first two used data up to 2007 and so will not accurately represent current mortality. Hinton et al. [32] conducted a survival analysis to identify factors influencing the timing and occurrence of mortality using data through September 2013 [32]. Like Hinton, we also analyze actual field data, rather than quarterly and annual reports. However, our data will now extend analysis through the 2018 season, a time period of policy change and dramatic decline in the red wolf population since Hinton's research. Where Hinton used only known-fate models, our analysis will include an estimation of those wolves with unknown fate.

Our specific objectives are to 1) determine mortality risk for 5 types of mortality (legal, poached, vehicle, nonhuman, and unknown) in the red wolf population from 1987 – 2018, 2) test for variances in mortality risk based on hunting season, and 3) compare "time/age to disappearance" for fate unknowns and time/age of death for different types of mortality for correlations.

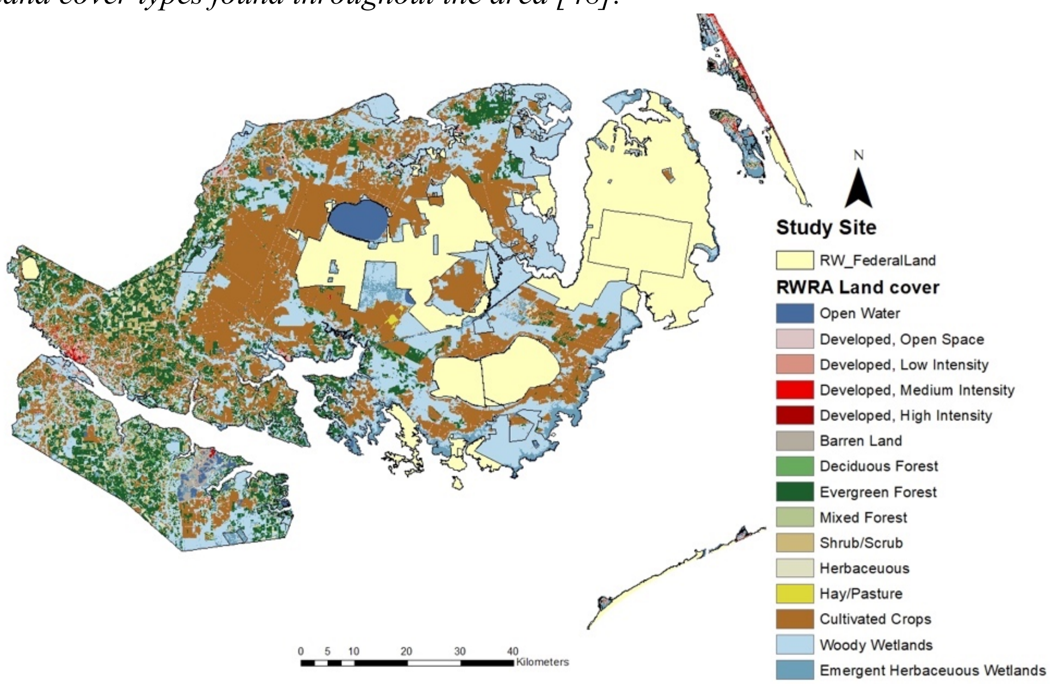
Materials and Methods

Study area

The RWRA consists of five counties on the Albemarle Peninsula in Northeastern North Carolina: Beaufort, Dare, Hyde, Tyrrell, and Washington. This area includes four USFWS managed National Wildlife Refuges: Alligator River, Mattamuskeet, Pocosin Lakes, and Swanquarter, a Department of Defense bombing range, and state-owned lands. Together the RWRA is comprised of 6,000 km^2 of federal, state, and private lands (Fig 2). Land cover types for the RWRA include 40% woody wetlands, 26% cultivated crops, 16% evergreen forest, 5% emergent herbaceous wetlands and other minor (less than 5%) land covers of developed (open space, low and medium), barren land, deciduous forest, mixed forest, shrub/scrub, herbaceous, and hay/pasture [48]. Elevation ranges between 0-50 m and climate is temperate with four distinct seasons [7].

Red wolves select agricultural habitats over forested areas and transient wolves select edges and roads in these areas more than residents [7]. This use of agricultural lands is in contrast to gray wolves in Wisconsin, which used these types of human landscapes less than expected by chance [14]. In a study on space use and habitat selection by red wolves, those that maintained stable home ranges in the area between 2009-2011 varied between 25 km^2 and 190 km^2, while transients would range between 122 km^2 and 681 km^2 [7].

Fig 2. Map of the Albemarle Peninsula of NENC showing federal and state-owned lands and land cover types found throughout the area [48].



Red wolf sampling

USFWS Monitoring

Since the implementation of the red wolf recovery program, the USFWS maintained consistent data collection to estimate abundance of red wolves and to provide context for determining observed changes [32]. Efforts were made to collar every individual, however, radio-collared wolves are not a random sample of all wild red wolves because trapping locations are limited to those areas accessible by USFWS personnel, unknown wolves may have wandered out of the 5-county recovery area (dispersers) or were never caught, and pups (<7.5 months) are not radio-collared for their own safety. Red wolves were captured on federal and state lands as well as private lands under memorandums of agreement or permission from landowners [7]. Originally this included 362,636 acres of public land, and 197,600 acres of private land, which has decreased in recent years. Red wolves typically mate in February with pups born in April or May staying in the den until they emerge 6 to 8 week later. Wolves were then captured and collared (adults) or pit-tagged (pups) in spring and fall of each year. Following Hinton et al. (2016) we define a red wolf year as October 1 – September 30 defined by the fiscal year for the USFWS.

The USFWS has maintained a database of all red wolves in the RWRA since reintroduction began in 1987 [49]. This database contains information on trapping, tagging, and demographic and spatial information collected and maintained by USFWS personnel for a total of 810 red wolves including adults and pups. USFWS red wolf database records include a suspected cause of death (COD), an official COD, and necropsy results if performed for each wolf of known fate (final outcome). These data were collected by the USFWS through field work, reports from trappers, private citizens, mortality signals from radio-collars and others [49].

We used population estimates from each year from three sources for red wolf population data: the USFWS database, Hinton et al. (2016), and the 2016 Red Wolf Population Viability Analysis [8,32,49]. Red wolf population numbers from these three sources were consistent until the year 2000 when they began to vary across sources. We do not know why the variation arose, so when the three sources varied, we used a range of red wolf numbers reported during that year. During certain analyses, we used the median of the range when sources differed. In more recent years, the USFWS published known population as well as estimates based on collared wolves combined with known or suspected uncollared red wolves from sightings and remote camera work or tracking, along with suspected litters or known litters that were not captured (USFWS).

Reported fates

We analyzed data for the 508 radio-collared adult red wolves between the years 1987 – 2018 (63% of all red wolves found in the database; the remaining 37% were pups or uncollared red wolves, which are not represented in our study). This includes 393 wolves of known fate and 115 wolves of unknown fate (Table 1).

We classified USFWS COD (known fates) into 5 classes: nonhuman, legal, poached, vehicle, and unknown cause (Table 2). Legal killing refers to legal removal by USFWS or by a permitted private individual, and legal killing is the only perfectly documented cause of death. All other causes of death have different amounts of bias depending on cause, which we refer to as inaccurately documented causes of death, following Treves et al. [12]. The Endangered Species Act made it illegal to kill a listed species except in defense of life [50], therefore, we define poaching as any non-permitted killing of a wolf such as shooting, poison, trapping, etc., even if the intended target animal was not a red wolf [14]. The USFWS listed 12 instances of suspected foul play, such as finding a cut collar but no wolf. We classified those as poached, following Hinton et al. [32], because there are only two possibilities with a cut collar; someone removed the collar of a wolf that had already died of another cause, or they killed the wolf, both of which are illegal. Nonhuman causes include mortality related to intraspecific and health related issues such as disease and age. While some of these types of deaths can be indirectly related to human activity such as habitat loss and disease exposure from domestic animals, we had no evidence they are directly caused by humans. We classified vehicle collisions as "vehicle" rather than poaching because the driver likely did not intend to kill a red wolf [12]. Finally, unknown causes include those whose COD could not be determined. These are important to include as discarding them creates an overrepresentation of perfectly reported legal killing.

Table 1: Mortality totals and FU totals for each year based on red wolf year of October 1 – September 30.
Red wolf population includes known population sizes for each year from 3 sources as well as estimated total population for more recent years as provided by the USFWS. COD and FU are for adult collared red wolves only.

Mortality and FU totals for wolf year Oct 1 - Sept 30							
	Population Est.	Poached	Unknown	Collision	Legal	Nonhuman	FU
1987-88	16	0	0	2	0	2	0
1988-89	15	0	0	1	0	2	0
1989-90	31	0	0	2	0	0	2
1990-91	34	0	0	2	0	4	0
1991-92	44	0	1	0	0	0	0
1992-93	67	0	0	0	0	2	1
1993-94	52	0	5	4	1	4	1
1994-95	44	7	3	1	1	2	2
1995-96	52	3	3	1	1	1	5
1996-97	46	0	1	3	2	2	3
1997-98	69	1	5	2	0	1	7
1998-99	90	3	2	0	2	4	10
1999-00	104	6	3	1	9	0	4
2000-01	96-108[1]	4	7	2	0	1	3
2001-02	97-121[1]	10	0	4	4	4	7
2002-03	102-128[1]	5	0	3	3	7	1
2003-04	113-149[1]	4	1	5	1	5	5
2004-05	125-151[1]	7	2	2	2	4	7
2005-06	126-143[1]	7	3	4	0	3	5
2006-07	116-134[1]	9	2	3	1	1	7
2007-08	115-137[1]	9	5	3	0	3	7
2008-09	111-138[1]	5	10	3	0	1	8
2009-10	111-135[1]	8	4	3	0	4	5

2010-11	112-123[1]	6	6	3	0	5	4
2011-12	104-127[1]	10	1	1	1	0	6
2012-13	103-112[1]	12	3	3	0	1	4
2013-14	113-149[1]	11	1	2	0	3	3
2014-15	74	11	3	0	2	0	4
2015-16	45-60[2]	3	7	2	0	0	0
2016-17	20, 25-35[2]	6	1	0	0	1	3
2017-18	19, 23-30[2]	2	2	3	0	0	1

[1] Reported population data varied among sources; numbers represent range of known population reported among all sources for each wolf year: the USFWS database, Hinton et al. (2016), and the 2016 Red Wolf Population Viability Analysis [8,32,49].

[2] Estimated population (USFWS) is based on known and possible unmonitored and uncollared red wolves from camera traps, known uncaptured litters, and sightings.

Table 2. Red wolf fates, our classifications of cause of death, and subtotals, 1987 – 2018 for 508 radio-collared adult wolves.

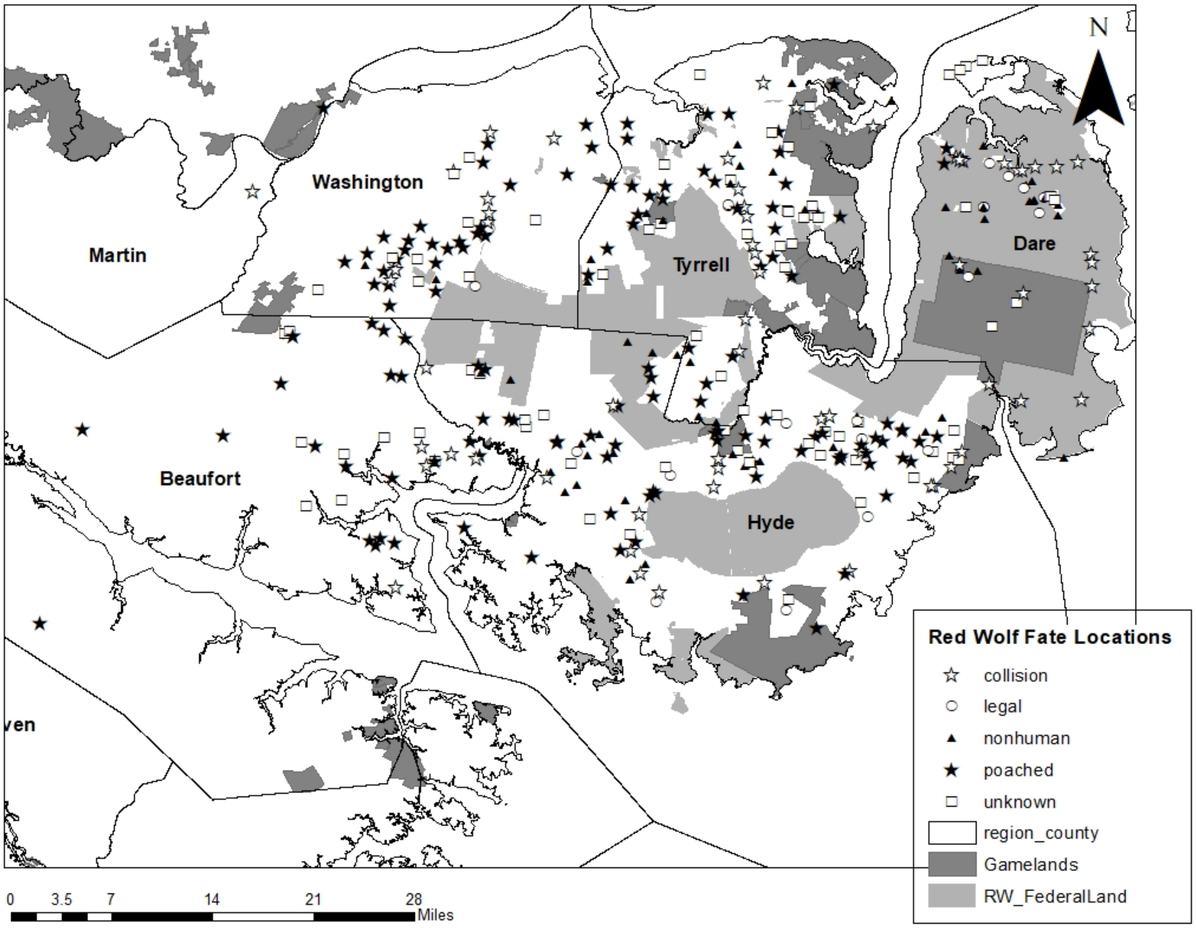
Data from USFWS red wolf database. The variables *n* (known fate subset) estimates the sum of reported fates with known COD, and *m* (unknown subset) estimates the sum of red wolves with fate unknown (FU) and unknown COD. Red wolves with unknown fate (FU) are those wolves who were radio-collared but were lost to USFWS monitoring

Cause of death (COD)	Our classification	USFWS data 1987 – 2018 for radio-collared adult red wolves
Management related Permitted activity	Legal	30
Gunshot Poison Trapping	Poached	149
Vehicle	Vehicle	66
Intraspecific Health/disease	Nonhuman	67
	Subtotal for n	**312**
Unknown cause		81
Fate unknown (FU)		115
	Subtotal for m	**196**

Almost all mortality records included spatial information, which we used to visually represent spatial patterns and will not be analyzed in this study. We included death locations at a more proximal scale (1:500,000) to protect exact locations of wolves and people who live in those areas (Fig 3).

Fig 3. Red wolf, Canis rufus, recorded death locations.

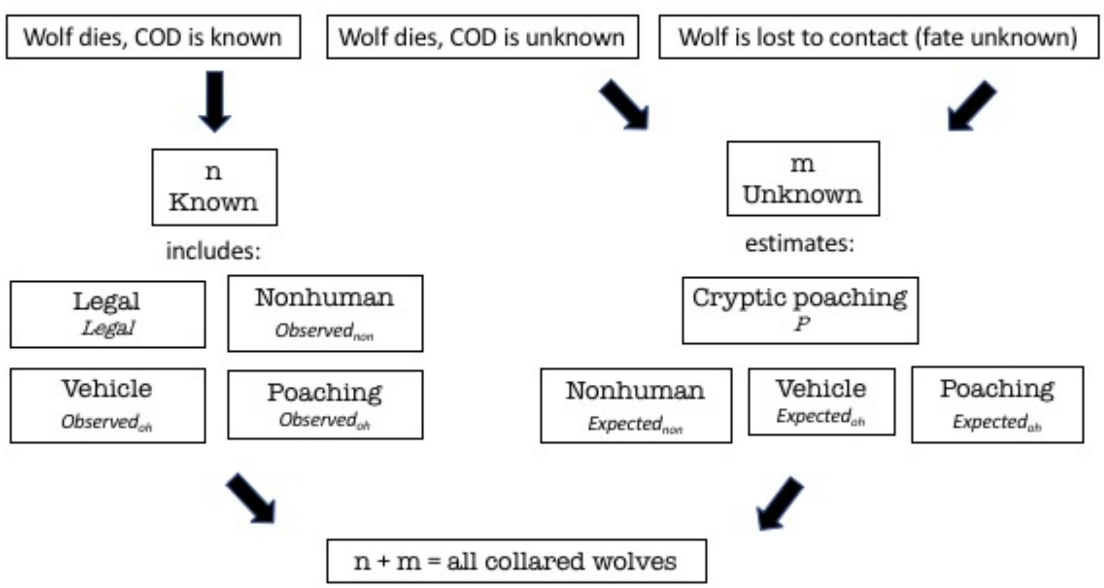
Only radio-collared adults with spatial information (n=370 individuals) from the USFWS database are represented. The remaining records did not contain spatial information. Scale 1:500,000.



Fate unknown (FU) wolves were lost to USFWS monitoring. Eventually the USFWS stopped monitoring these collars because they could not locate the red wolf through aerial or ground telemetry. This could happen if the collar stopped working or if the wolf is killed and the collar is destroyed to conceal the evidence, referred to as “cryptic poaching” [12,21]. The USFWS assigned their FU date as the date of last contact. Any red wolves who were declared FU, but then later recovered dead, were assigned a COD by USFWS. Those collared red wolves that might still be alive but unmonitored (FU) at the time of this analysis were still included in our analysis because they are likely to be dead as of writing and failure to include them could bias estimates of risk against imperfectly reported COD, especially poaching associated with collar destruction.

We could calculate the risk of each cause of death as a percent of known fates as is traditional, but that would disproportionately bias against the imperfectly reported causes that comprise the FU and it would leave us with a substantial risk of unknown cause, which is not informative. Following the method in (11) instead, we estimate risk more accurately by taking into account how many of *m* to reallocate from the unknown causes and the FU in Table 2 to our three classes of cause of death that we know are the imperfectly reported CODs. The reallocation step is an estimation procedure with several variant methods that apportion different amounts of *m* to poached, vehicle, or nonhuman, depending on assumptions that we explain next (Fig 4).

Fig 4. What happens to dead or missing collared wolves.
$Observed_{non}$ is the number of marked animals of known fate that died from nonhuman causes. $Observed_{oh}$ is the number of marked animals of known fate that died of vehicle and poaching (human COD other than legal). $Expected_{non}$ is the number of marked animals of unknown fate expected dead from nonhuman causes and $Expected_{oh}$ is the number of marked animals of unknown fate expected dead from vehicle and poaching. P is the estimation of wolves dead from cryptic poaching.



Estimating risk from different causes of death

Risk is defined as the proportion of all deaths attributable to a given cause. For example, if five out of ten wolf deaths are the result of poaching, then wolves in that population had a poaching risk of 50%. This is different from mortality rate, which is the rate of individuals dying per unit time [14]. To estimate risk accurately, we need the denominator to be all collared red wolves ($n + m$, Fig 4). With n=312 wolves with information on COD and m = 196 wolves without information on COD (Table 2), the denominator for all risk calculations and estimates would be 508. A summary of the method for accurately estimating risk is provided below but see [12] for a full description of the method.

First, we calculated the risk of legal killing, in a straightforward manner because they are all known fates and there are none in m, the unknown fates portion (Fig 3). Legal killing is never represented in the unknown fates because they must be reported to be legal, by definition [14]. Therefore, we had to recalculate the risk posed by the 30 cases of legal killing (Table 1) with the denominator, $n + m$, to calculate risk of legal kill for all collared red wolves, which yields an estimate of risk of 5.9% (Table 5). Without this correction, risk of the 30 cases of legal killing in Table 1 would be overestimated as 9.6%. When one overestimates the risk of legal killing, one underestimates all other imperfectly reported CODs.

Table 3. Risk of legal killing among collared red wolves

	Known fates (n)	**Unknown fates (m)**	**Known + Unknown fates (n+m)**
Legal killing	legal/n	0	legal/(n+m)
Legal killing	30/312 = 0.096	0	30/508 = 0.059

With the straightforward case of legal killing recalculated as explained above, it is easier to explain how to account for the imperfectly reported CODs within m (Fig 4). The unknown fate collared wolves in m contain only imperfectly reported CODs but an unknown number of each category of nonhuman, vehicle, and poached, which we define below. Therefore, we must turn to estimation techniques whose uncertainty produces bounds on our values. The 2 sources for *m* in figure 4 are unknown COD and FU. We have defined all possible CODs so all unknown fates must be allocated to nonhuman, vehicle, or poached. There are no other causes of death than our categories but the occurrence of transmitter failure and destruction of transmitters in the FU subset does create a subcategory of poaching.

Transmitter failure that leads to an animal evading monitoring while the wolf is alive can happen for any of these CODs. When a transmitter fails and the animal is poached, it is not necessarily cryptic as the transmitter might fail before poaching and the poacher may not have tried to conceal the evidence. However, when the transmitter is destroyed by the poacher (rather than transmitter failure), then we define it as cryptic poaching. Cryptic poaching involves the destruction of evidence [21] distinguishing it from "regular" poaching that is present in both *m* and *n*. This is the reason there are 3 types of poaching in Fig 4; "regular" observed poaching in *n*, "regular" unobserved poaching in *m* after transmitter failure, and cryptic poaching in *m* after transmitter destruction. This changes the way in which we estimate poaching because there may be a subset of cryptic poaching in *m* that is never represented in our known fate subset. The estimation of COD in *m* requires that we consider the possibility of cryptic poaching with transmitter destruction before we allocate *m* to the three "regular" CODs.

Previous work [12] assumed the lower estimate of cryptic poaching was zero. However, we assume non-zero cryptic poaching in the NENC red wolf population because at least 23 observed poaching incidents in *n* show evidence of attempted and failed cryptic poaching (tampering or damage to the transmitter did not cause its failure, so the USFWS recovered the collar or carcass even though the poacher tried to conceal it). We categorized these 23 as failed cryptic poaching based on the following circumstances; only a damaged collar was found, the dead wolf was found with a damaged collar, or the dead wolf was discovered in a suspicious location. Locations included being dumped in the canal, one was with a beagle that had also been shot (also found in that canal), and one was in the same location as another shot wolf was found. In the case of a damaged collar, damage included obvious human tampering such as bullet holes and knife cuts. These 23 deaths include 12 instances categorized by the USFWS as suspected foul play and 11 poaching events with suspicious circumstances recorded in field notes.

The destruction of a transmitter occurs earlier than transmitter failure and so when we estimate it, we will deduct the estimate of cryptic poaching from *m* first, before we assign the rest of *m* to nonhuman, vehicle, and "regular" poaching. Scenario planning is a powerful tool for exploring uncertainty and by using it to estimate poaching, analysis can move from trying to estimate one "most likely" outcome to challenging assumptions and broadening perspectives [51]. Following [12], we used 3 scenarios to estimate cryptic poaching (P) explained next.

Scenario 1 assumes that poachers who tamper with evidence are equally successful as unsuccessful, so the risk of cryptic poaching in *n* is the same as the risk of cryptic poaching in *m*. Therefore, we estimated cryptic poaching as 23/*n* (23/312 = 0.074) meaning for each observed dead wolf, we expect 0.074 unobserved deaths from cryptic poaching and applied that estimate to *m*, hence P = 0.074 *m = 14.4. For this scenario and the ones that follow, we estimate expected numbers for nonhuman, vehicle, and poaching as follows:

$$Expected_{non} = (m-P) * Observed_{non}/Observed_{non}+Observed_{oh}) \quad \text{(equation 2a)}$$

$$Expected_{vehicle} = (m-P) * Observed_{vehicle}/Observed_{non}+Observed_{oh}) \quad \text{(equation 2b)}$$

$$Expected_{poached} = (m-P) * Observed_{poached}/Observed_{non}+Observed_{oh}) \quad \text{(equation 2c)}$$

where "other human" (oh) is wolves dead from regular poaching plus vehicle collisions.

For scenario 2 we assume all wolves that are classified as FU in USFWS database were the result of cryptic poaching but none of the unknown COD were the result of cryptic poaching. While this might over-estimate a few cases of transmitter failure, it might under-estimate the cryptic poaching in unknown COD cases that might include poison or other killing that was concealed by decomposition or other illegal actions. Therefore, for scenario 2, P = 115.

For Scenario 3 we rely on the published estimate of cryptic poaching for Wisconsin wolves, of 46% – 54% meaning that for each observed poached wolf, 1 was unobserved (cryptic) [12]. We applied that estimate to our population which has 149 poached wolves in *n* giving us P = 149 for scenario 3. Treves et al [12] also used a published estimate for Scandinavian wolves of 66%, meaning that for every 1 observed poached wolf, there were 2 cryptic [21]. However, that risk estimate is unrealistic for our population because it would imply P > m.

Table 4. The general expression for any (n) known fates, and (m) unknown fate with 3 causes of death.

Adapted from Treves et al [12]. Categories listed are defined as follows: Legal (marked animals killed legally, the only perfectly documented cause of death), $Observed_{non}$ (number of marked animals of known fate that died from nonhuman causes), $Observed_{oh}$ (number of marked animals of known fate that died of human causes other than legal), $Expected_{non}$ (number of marked animals of unknown fate expected dead from nonhuman causes, $Expected_{oh}$ (number of marked animals of unknown fate expected dead from human causes other than legal), P (number of marked animals of unknown fate expected dead from cryptic poaching equation 1). Unknown fates include recovered carcasses with unknown causes of death and FU.

	Known fates (n)	Unknown fates (m)	Known + unknown fates (n + m)
Legal killing	legal/n	0	legal/(n+m)
Nonhuman causes	$Observed_{non}$/n	$Expected_{non}$/m	($Observed_{non}$+$Expected_{non}$)/(n+m)
Other human causes	$Observed_{oh}$/n	$Expected_{oh}$+P/m	($Observed_{oh}$+$Expected_{oh}$+P)/(n+m)

Finally, we estimated the total risk of poaching with $Observed_{poached}$+$Expected_{poached}$+P divided by n+m, rather than $Observed_{poached}$/n as has often been done (11). From observed and expected poaching, we can estimate total poaching (observed and cryptic).

Timing of death and disappearance

Season

We calculated monthly risk for different CODs and used a chi-square analysis to evaluate whether the monthly distributions of CODs were different. We then used a binomial test to evaluate whether the proportion of various CODs that occurred during hunting season (September 12 – January 31: includes all fall/winter hunting of black bear, deer, and waterfowl) was significantly different than expected, given the length of hunting season is 141 days. Finally, we used a chi-square test to evaluate whether various CODs occurred in different proportions to each other during hunting season vs non-hunting season. Since NC issues nonresident hunting licenses, and several large hunting clubs operate within the five-county RWRA, there is an influx of hunters during the hunting period. This ushers in a higher risk of poaching for red wolves, whether it is due to hunting season or simply the influx of people that could shoot a red wolf. Using data from 1987-2013, Hinton et al showed a dramatic decrease in survival during the months of October through December [32].

Individual survival

The amount of time individual red wolves spent in the wild was calculated from their collaring date to the date of death (with COD) or disappearance (FU). Time to disappearance for unknown fates was calculated by subtracting the date of last contact (end point) from the date they were collared (starting point). Time to death was similarly calculated. All results are presented in mean days. We then visually compared time to endpoint for red wolves that were poached in the known fate subset with those red wolves of unknown fates.

We also compared both mean time in the wild and mean age at death or disappearance for each of the 5 fates (4 CODs and FU) using a one-way analysis of variance (ANOVA). Tamhane's T2 post-hoc test (used for unequal variances) was then used to test where pairwise differences occurred between each COD and wolves with unknown fate. We conducted all analysis in STATA IC 15.1 for Mac (StataCorp, College Station, Texas, 2019).

Results

Estimating risk from different causes of death

From 508 adult radio-collared red wolves, we estimated the risk of legal killing as 0.059 which is lower than the USFWS estimate of 0.13 [34] and higher than previously published studies of 0.04 – 0.05 [32,38,47]. Relative risk of mortality from human causes of death other than legal killing ranged from 0.724 – 0.787 depending on the three scenarios for level of cryptic poaching in the population (Table 5). When unknown fates were included in risk calculations, risk of mortality from inaccurately documented causes of death (red wolves that died from human causes other than legal killing) was 0.026 - 0.044 higher than Treves' corrected risk estimate using data from 2007 [47], which was 0.26 – 0.40 higher than government estimates using data from 1999-2007 [34].

Table 5. Risk of mortality from legal, nonhuman and other human CODs from known fates (n) and 3 cryptic poaching scenarios (P) affecting m, which is the number of wolves of unknown fate.

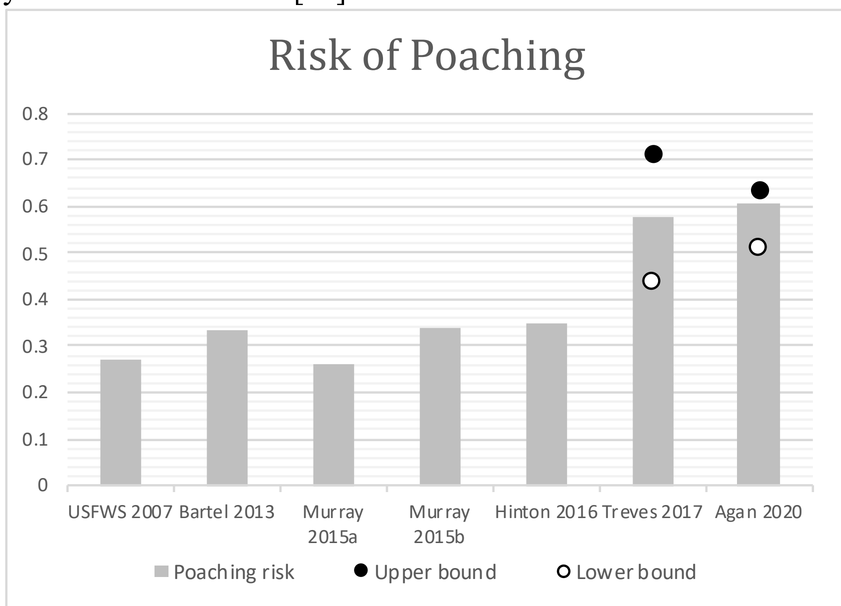
Estimates calculated using equations 2a – c and Table 3.

		Scenario 1, P=14.4		Scenario 2, P=115		Scenario 3, P=149	
	Risk in *n*	*m*	*n+m*	*m*	*n+m*	*m*	*n+m*
Legal killing	0.096	0.000	0.059	0.000	0.059	0.000	0.059
Nonhuman causes	0.215	0.220	0.217	0.098	0.170	0.057	0.154
Other human	0.689	0.780	0.724	0.902	0.771	0.943	0.787
Vehicle	0.212	0.217	0.214	0.097	0.167	0.056	0.152
Total poaching	0.478	0.563	0.511	0.805	0.604	0.887	0.635
Cryptic poaching	0.000	0.074	0.028	0.587	0.378	0.760	0.342
Regular poaching	0.478	0.489	0.482	0.218	0.226	0.127	0.293

[a]Risk for total poaching and vehicle are % of n and total to "other human" risk. Total poaching is further broken down into cryptic and regular poaching.

Using the cryptic poaching P = 115 scenario, the risk of mortality from poaching, as a proportion of all deaths has a middle value of 0.604, which is higher than all previously published estimates including 0.33 higher than government estimates (0.27) and 0.029 higher than Treves 2017 corrected estimate (0.575) (Fig 5). In this scenario, cryptic poaching accounts for 0.63 of all poaching.

Fig 5. Risk of mortality from poaching as a proportion of all deaths.
Bars represent poaching risk estimates from different studies for the NENC red wolf population. Treves 2017 and Agan 2020 (this study) represent 3 scenarios of cryptic poaching with a lower, middle (bar) and upper bound for each. Years of data used vary for each study: our estimates use data from 1987-2018, Treves 2017 [12] data years are 1999 – 2007 [34,47], USFWS 2007 data years are 1999 – 2007 [34], Bartel 2013 data years are 1987 – 2012 [38], Murray 2015a data years are 1999 – 2007 [47], Murray 2015b data years are 2009 – 2014 [47], Hinton 2016 data years are 1987 – 2013 [32].



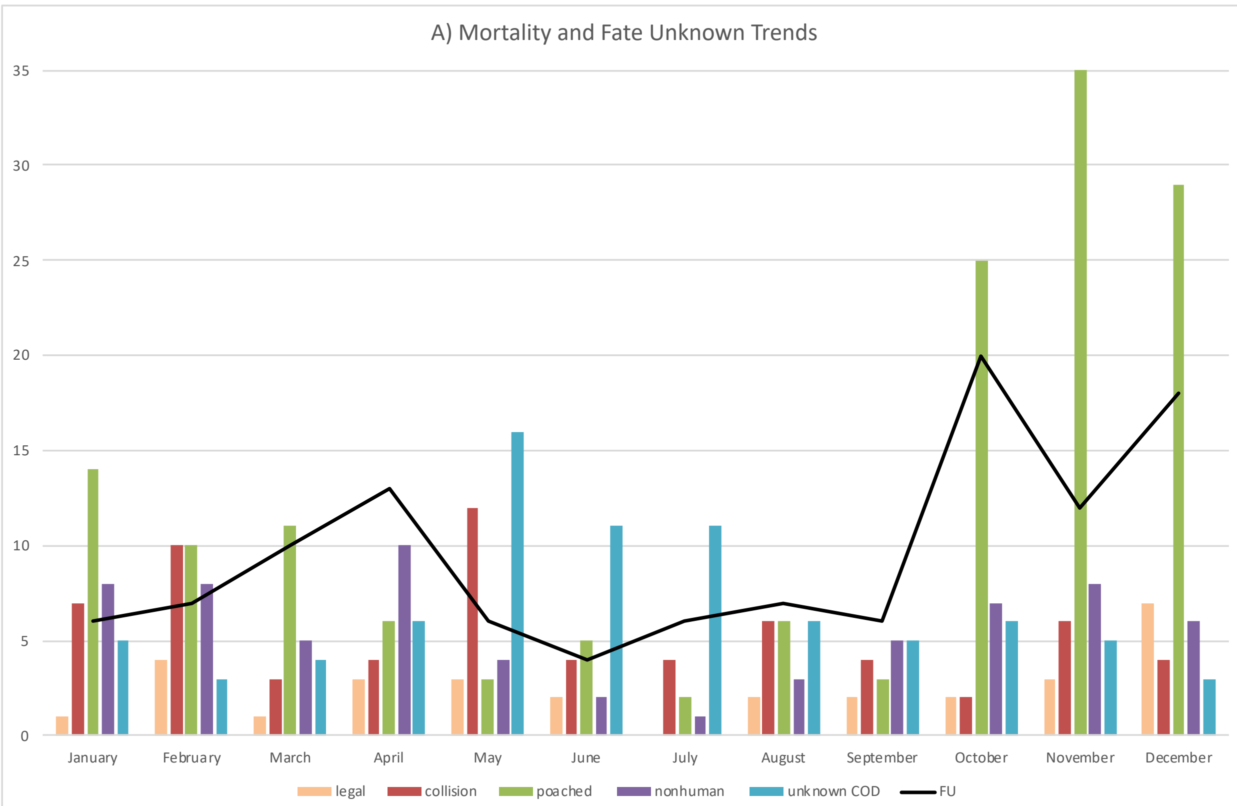
Timing of death and disappearance

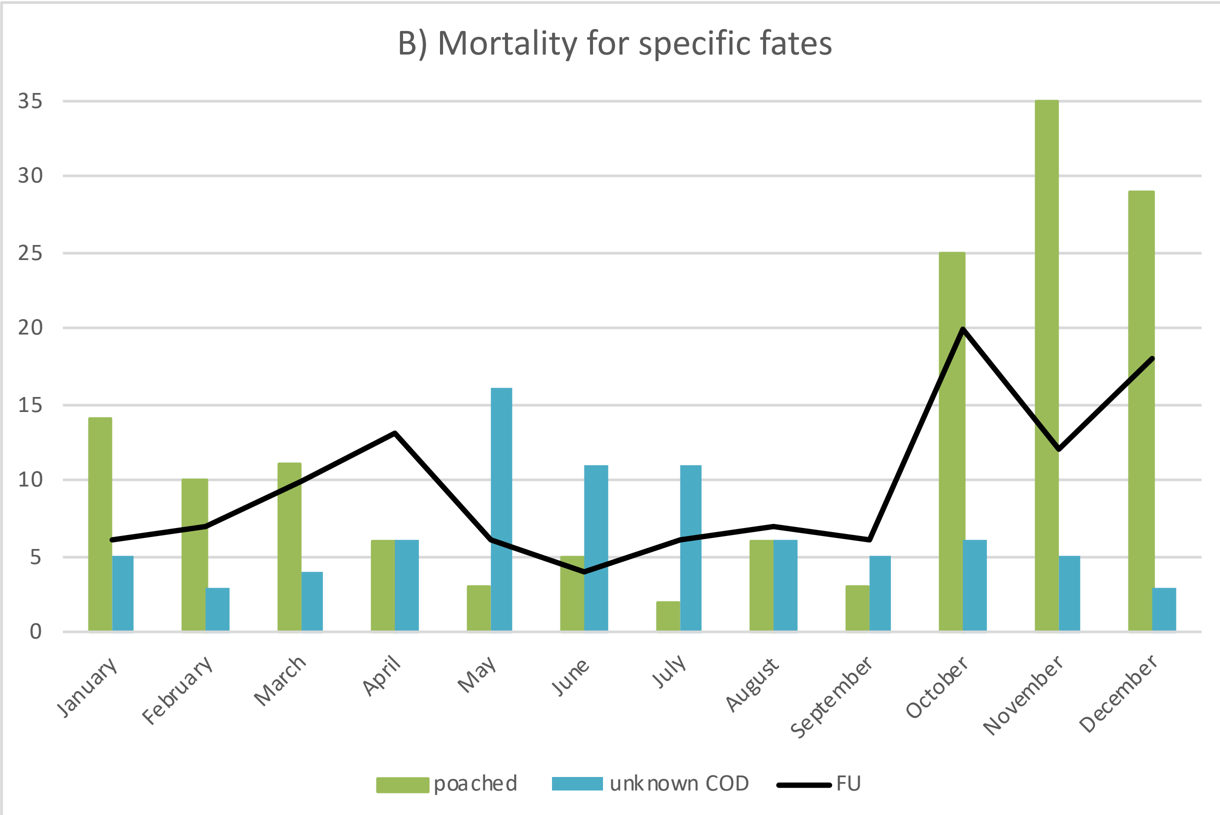
Season

Monthly distributions of COD differed significantly from chance (c^2 = 136.7, df=55, p < 0.001). The number of red wolves poached increased from October through December compared to other months during the years of this study (Fig 6), coinciding with the fall/winter hunting season. Those 4 months account for 61% of all red wolves that have been poached (October *n*=25, 17% of all red wolves poached during the year, November *n*=35, 24%, December *n*=29, 20%) more than double what one expects by chance (25%). The numbers of collared red wolves that disappeared (FU) also increased during the same 3 months.

Fig 6. Mortality each month (bars) compared to the number of fate unknown red wolves (black line).

A) Total mortality during each month for all COD's represented as bars. Fate unknowns are represented with a black line since there is more uncertainty with date of disappearance and line is more representative of the continuity of time. B) Total mortality for poached, unknown COD, and fate unknown, 3 fates which we consider important for our discussion.

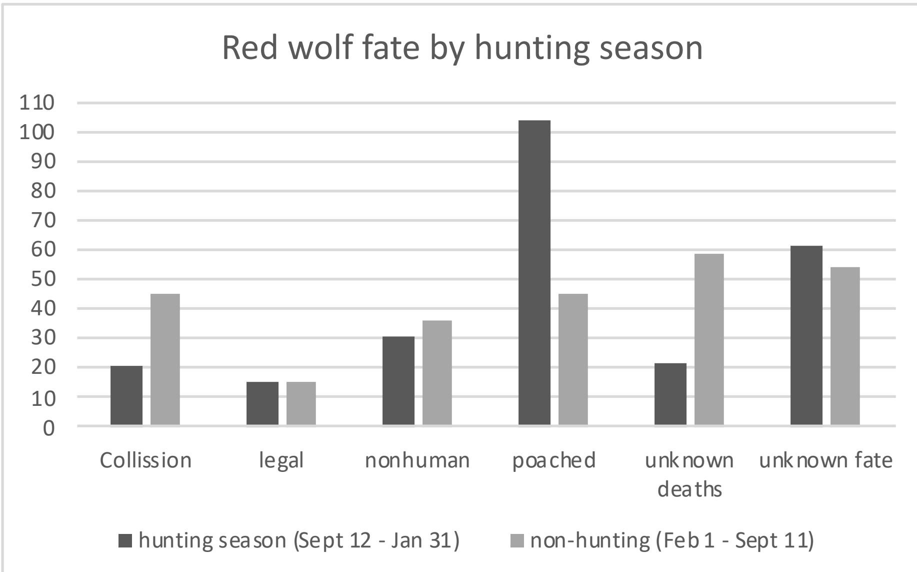




Using a binomial test, two fates occurred in significantly higher proportion than expected during hunting season, given that it lasts 141 days, or 38.6% of the year: fate unknowns (61 of 115 occurred in hunting season, $p < 0.001$) and poached (104 of 149 occurred in hunting season, $p = 0.04$). Unknown COD was significantly lower than expected during hunting season (22 of 81, $p=0.04$). (Fig 7).

Fates occurred in significantly different proportions to each other when comparing hunting and nonhunting season ($c^2 = 49.79$, df=5, $p < 0.001$). We then tested for specific associations and found poached and FU occurred in significantly different proportions from each other during the two time periods ($c^2 = 7.77$, df=1, $p = 0.005$), as did FU pooled with unknown COD compared to poached ($c^2 = 25.7$, df=1, $p < 0.001$).

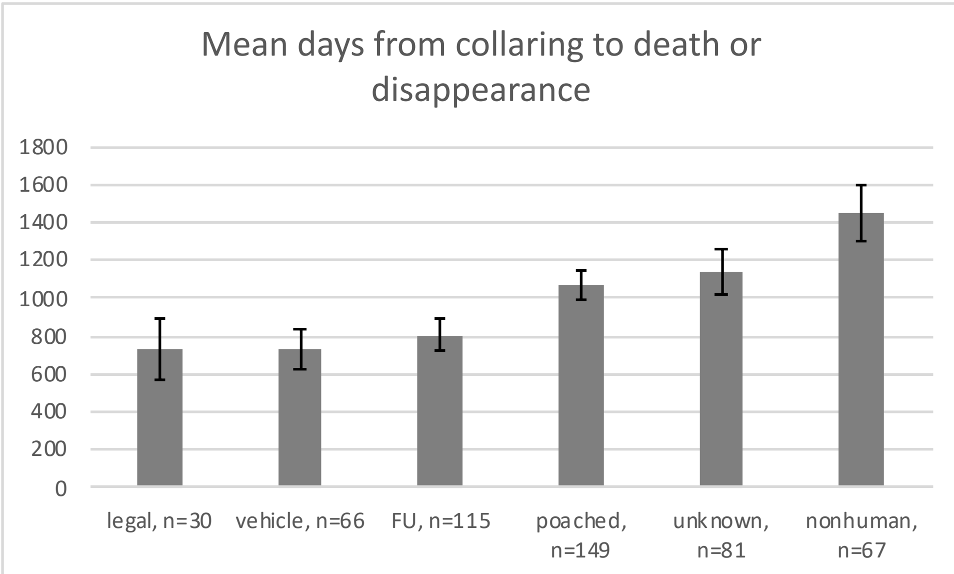
Fig 7. Total numbers of red wolf deaths for each type of mortality and unknown fates during hunting season (dark gray bars) and non-hunting season (light gray bars).
Hunting season is inclusive of all fall/winter hunting including white-tailed deer, black bear, and waterfowl.



Time in the wild

Time to death or disappearance for all adult collared red wolves was 1009 ± 45 days. Days from collaring to death ranged from 0 to 4,651 days with a mean of 1067 ± 52 days (95% CI – 965, 1170) (Fig 8). All human-caused, unknown deaths, and disappearances lead to fewer mean days in the wild than wolves that died from nonhuman causes (Fig. 8). We found significant differences between FU and different CODs using ANOVA ($F(5,502) = 5.72$, $p < .001$). Because Bartlett's test statistic of 15.04, $p=.01$ shows significant difference in variances, we used Tamhane's T2 post hoc test for unequal variances to evaluate pairwise differences. Nonhuman was the only COD that significantly differed from FU (CI = 114.8, 1168.4). FUs were most similar to poached (CI = -112.3, 578.5), and unknown COD (CI = -34.8, 775.4).

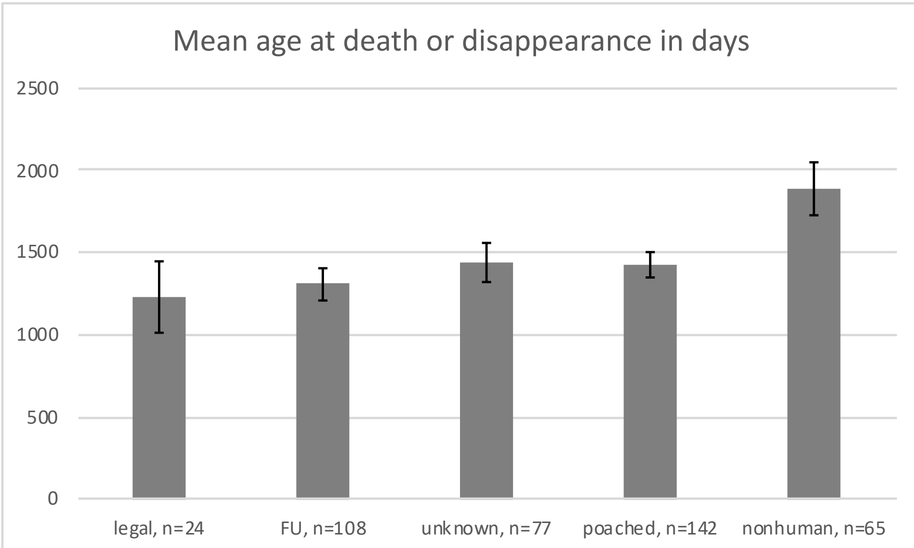
Fig 8. Mean days from collaring to death or disappearance.
Mean days represents length of time from capture and collaring to the date of death or date established as fate unknown (date of last contact) for all collared adult red wolves. Bars represent SE.



Age at death or disappearance

There were statistically significant differences between the mean age at death or disappearance for the various CODs (F(5,476) = 4.04, p = .0013), and Bartlett's test statistic was 9.91, p=0.08. We ran a Tukey's tests for pairwise comparisons between FU (1307.5 ± 99 days) and nonhuman COD (1886 ± 160 days) (p = 0.006). All other pairwise comparisons were not significant (Fig 9).

Fig 9. Mean age at death or disappearance.
Mean days represents length of time from birth to the date of death or date established as fate unknown (date of last contact) for all collared adult red wolves. Date of birth was unknown for some red wolves so only those with a recorded date of birth in the database were used, *n* = 416. Error bars represent SE.



Discussion

We found that anthropogenic causes of death are responsible for 0.724 – 0.787 of all red wolf deaths when considering all collared adult red wolves (including both known n + unknown m fates), depending on our estimate of cryptic poaching in the population. Estimate for risk of legal killing decreased from 0.096 in known fate to 0.059 when both known and unknown fates were considered. We estimated poaching at 0.51 – 0.635 of total deaths, with cryptic poaching alone between 0.028 and 0.378 (5-63% of poaching).

Poaching, unknown cause of death, and fate unknown (we also refer to as disappearances) were the 3 fates that showed significant departure from expected outcomes during hunting season. Poaching and FU were significantly higher while unknown COD was significantly lower during this time. Wolves with unknown COD were more prevalent in the summer months of May – July possibly because hot summer temperatures speed decomposition of carcasses that take days to weeks to detect and recover.

Mean time in the wild for poached red wolves was approximately 2.9 years, which was more than a year less than those who died of nonhuman causes. FU had a mean time in the wild of only 2.2 years, almost two years less than nonhuman COD. However, legal killing and vehicle, both 2.0 years, accounted for the shortest time in the wild for all red wolves. Results were similar for age at death or disappearance where legal at 3.4 years, and vehicle at 3.1 years reported the youngest age at death while poached mean was 3.9 years and FU mean was 3.6 years, all lower than mean age for nonhuman causes of 5.2 years.

Our results for risk of various causes of death, when compared to previous published estimates, support the need for including unknown fates in risk estimates. Legal risk would have been overestimated using only a known fate model, leading to other imperfectly reported CODs being underestimated, first predicted by [12]. By summing known and unknown fates, our risk from anthropogenic causes is higher t at 0.78 whereas previous estimates ranged from 0.45 [47] to 0.61 [29]. The last corrected estimate (conducted with our same method) using data through 2007 [12] was slightly lower than ours at 0.77 suggesting a slight increase in anthropogenic mortality since that time.

Our most conservative risk of poaching of 0.51 is also higher than any previously published risk estimate, which ranged from 0.26 [47] to 0.44 [12]. Our conservative scenario assumes the least amount of cryptic poaching whereas our other scenarios estimate cryptic poaching at 0.54 and 0.63, similar to the Wisconsin estimate of 0.50 [12] and the Scandinavian estimate of 0.66 [21]. All three of our red wolf scenarios lead to very similar poaching risk, suggesting that regardless of the scenario evaluated, wolves in NENC are at higher risk from poaching than any other cause of death. This supports previous work that suggested poaching might be the cause of decline of this introduced population compared to success in other populations like Yellowstone [52]. We also suspect poaching of red wolves is higher than any other population measured thus far.

We observed an increase in risk of poaching during the late fall hunting season. Other studies have shown similar population declines during this same time period in red wolves [32], gray wolves [14], and coyotes [53]. Just before fall hunting season, agricultural fields, which make up approximately 30% of the red wolf recovery area [7], are typically cleared in this region and may contribute to that increased risk with decreased cover for wolves to hide [32]. This pattern is quite different from patterns during regulated summer hunting for turkeys from April – May when fields are in production and there is no significant increase in poaching of red wolves. Turkeys are very different from red wolves so we wouldn't expect mistaken identity, however any type of hunting can mean more opportunity for poaching. In our study, all other mortality risk decreases (vehicle, nonhuman, unknown) or remains the same (legal) during hunting season. However, red wolves that disappear (FU) also increase during hunting season, suggesting a possible relationship with poaching and supporting our assumption that many FUs represent cryptic poaching events (scenario 2). Wolves that are poached or disappear during this time period usually have additive effects on the population since hunting season coincides with pair bonding and can result in the loss of breeding opportunities for the following year.

All anthropogenic CODs shorten the time that red wolves spent in the wild until they died or disappeared compared to those dying a natural death. Legal killing and vehicle collisions had the largest influence by reducing time in the wild by half. Disappearance, poaching and unknown COD also decreased time in the wild by 44%, 26%, and 22%, respectively.

Mean age at death for all red wolves was 1444 days, or 3.9 years, which was an increase of 0.7 years since Hinton et al. estimated it at 3.2 years. Anthropogenic mortality caused a dramatic decrease of 563 days or 1.54 years in the wild. Those wolves that died of nonhuman causes lived to the average age of 5.2 years while those who died of human causes and those who disappeared (FU) only lived to an average 3.6 years. Given wolves usually begin breeding around the age of 2, those that died naturally are able to reproductively contribute to the population for 3 years, twice as long as those that died of human causes. This early removal of red wolves would be expected to lower both birth rate and growth rate for the wild population.

We reported locations of deaths to visually analyze any trends on the landscape over the first 31 years of reintroduction. We found clusters of poaching deaths in every county, most of which are away from major roads and all but two are on private land. This could be due to the presence of higher detection and/or enforcement in the refuges and as such, relatively lower detection and lack of enforcement on private lands for would-be poachers. Also, most poaching deaths were in large agricultural fields with many immediately adjacent to federal land. This spatial picture is incomplete since fate unknown wolves are absent. They could be included by mapping the last known location although this measure would contain more error than most death locations. We recommend a spatial analysis that includes a more in-depth study of both types of locations along with fate unknowns that includes ecological and social aspects of the landscape that can influence red wolf mortality. Poaching risk has changed over time and so locations and timing of poaching and unknown fates in particular would be useful for management decisions in anti-poaching efforts.

Analysis for this study relied on USFWS data for COD and disappearances because we could not verify these independently, which is a limitation of this study. Also, the USFWS has not used GPS collars on red wolves since 2013 and VHF location data includes death locations but not wolf movements. Previous survival analysis on wildlife populations have not accounted for certain causes of death and disappearance such as policy changes, nor have they been able to model how individual wolves experience policy over time. They don't accurately represent wolves who disappear (FU) since most are censored and not included in outcomes. While survival analysis can model changes in hazard rates, it does not verify why those changes take place such as possible social reasons for increased or decreased poaching. We recommend a time-to-event survival analysis that includes policy period as a hazard since increased poaching appears to be correlated with political volatility.

Considering the amount of poaching that occurs on private lands, working with landowners is crucial to red wolf survival. This is not a new idea as it has been offered in most discussions of red wolf research, particularly those focused on social science. However, the methods by which red wolf management has been implemented in NENC has not been adequate to reduce poaching behavior. Routine Activity Theory [54] establishes three needs for poaching opportunity: lack of guardianship (anti-poaching forces), a would-be poacher, and suitable target (red wolf). Guardianship can come through many different anti-poaching strategies but what actually works is difficult to study. Much of our understanding comes from either models of human behavior that are difficult to validate [55], or interview methods such as Randomized Response Technique (RRT) [56].

St. John et al. (2014) reported that the decision not to poach was most related to four main social norms; belief that others would disapprove, belief that others did not poach, high probability of detection and punishment, and feelings of guilt related to poaching. This is useful to managers since social norms can differ regionally, and it would be important to harness those social norms that encourage compliance while also being careful not to break down existing norms (such as trust) that discourage poaching. We recommend social science research to determine what those norms are for this area of North Carolina.

Successful change in behavior of would-be poachers depends on changing the incentive for poaching and should include strategies to encourage abiding by rules. Keane (2008, 2012) found that increasing fines per animal was the most effective way to reduce poaching [55,57]. However, harsh enforcement can be at odds with improving relationships between government and the local community, creating a management challenge.

The USFWS will need to implement favorable policy that prohibits, and interdicts take of red wolves. Killing of red wolves for any reason, other than defense of human life, may actually devalue wolves leading to increases in poaching [9]. Rather, programs that reward the presence of wolves can increase their value to local residents. One example of favorable policy related to carnivores was the wolverine program in Sweden, which offered rewards to Sami reindeer herding communities for having reproducing female wolverines on their communal lands [20]. Across North America, success of carnivore populations has been linked to management policy and enforcement [17] and managing wolves successfully, by protecting wolves and encouraging acceptance, is one way to generate support for their restoration [37]. In NENC policy has changed at both the state and federal level several times since reintroduction began and is currently being reviewed for further changes. This makes it difficult for residents to understand what current regulations are and can lead to confusion about what is allowed or not allowed with regard to killing red wolves. To maintain a positive working relationship with private landowners, USFWS will need to adapt and enforce policy that is consistent, clear, and protects wolves throughout the entire red wolf recovery area even if it means standing up to illegal actors and communities that condone such law-breaking.

Because approximately 76% of the RWRA is private, any anti-poaching measure implemented in NENC must be proven to work on private lands. Knowledge of wolves' locations through radio-collaring, camera traps, and other methods simplify all aspects of management by allowing biologists to locate wolves for any reason including human conflict and should be a part of anti-poaching management. In the past, the USFWS had access to approximately 197,600 acres of private lands through both written and verbal agreements. This has decreased in recent years, both because there are fewer wolves on private land, and because some landowners are no longer as supportive of the program or as willing to allow access. Some of this is the result of changes in coyote hunting or their frustration from feeling like the red wolf has infringed on their private property rights (USFWS personal communication). Good relationships with landowners that provide access to private lands may not only increase USFWS knowledge of red wolves located there but might also contribute to anti-poaching strategy.

This study makes it explicitly clear that aggressive interventions must happen to reduce poaching immediately if there is going to be any chance the remaining 19 red wolves can create a self-sustaining population. In their most recent 5-year review completed in 2018, the USFWS recommended the red wolf retain its status as endangered under the ESA [58]. While there have been significant changes in the RWRA since reintroduction began, such as the migration of coyotes into the area and problems with poaching, the area still retains most of what made it appealing to reintroduction in the first place including low human density and suitable habitat. With the Red Wolf Adaptive Management Plan [59], the USFWS took an aggressive and successful approach to the encroachment of coyotes and should do the same with poaching. The past has proven that wolves can successfully re-establish, both naturally and through reintroduction, where they once were extirpated in the wild including gray wolves in Yellowstone [4], gray wolves in Wisconsin ([14] and Mexican wolves in Arizona and New Mexico [60]. Implementing proven practices that prevent poaching or hasten successful reintroduction can reverse the trend of a decreasing NENC red wolf population and once again allow red wolves to thrive, not only in NENC but additional future reintroduction sites.

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Chapter 3: Landowner attitude toward red wolves (*Canis rufus*): implications for red wolf survival in northeastern North Carolina

Suzanne Agan

Antioch University New England

Abstract

In December 2018, there were an estimated 23-30 individuals remaining in the only wild population of red wolves, located in Northeastern North Carolina (NENC). Anthropogenic mortality is the largest threat to survival of this population and by understanding how people think about red wolves, what their behavioral inclinations are, and how attitudes are distributed geographically, decisions can be made about how and where to concentrate outreach efforts. Our goal was to conduct interviews and surveys in nine counties in and around the NENC reintroduction area to measure attitude, experience and behavioral inclinations toward red wolves and acceptance of the red wolf program. We collected two different samples that included a pre-recruited panel and convenience sample with significant differences between them. Overall, we found the majority of respondents' attitudes to be positive toward both red wolves and their conservation and those who dislike them are in a small minority. Those who emerged as the least positive toward red wolves and their conservation were those who identified as male and hunters. There is also a large percent who do not know or are neutral about the program and more than half have only had indirect experience with red wolves. Our study highlights the importance of relationship and communication between agency personnel and landowners, not only in response to wolf-human interactions but throughout the entire process of recovery including decision-making. Currently we don't know what the future for red wolves in NENC will be. Research that is interdisciplinary and involves reconciliation ecology will be needed to conserve red wolves within these human-dominated landscapes.

Key words

Red wolves, attitudes, poaching, behavioral inclinations, mixed method, conservation

1. Introduction

Critically endangered red wolves, *Canis rufus* were extinct in the wild and had been absent for over 100 years from eastern North Carolina when they were reintroduced from captive-born individuals in 1987 (Barclay, 2002). Once abundant throughout the eastern US from the Atlantic Coast west to Texas and from the Gulf of Mexico north to the Ohio River Valley and central New York (Figure 1), red wolves were eradicated, in part through government-sponsored eradication programs, as Europeans migrated and settled throughout the US east of the Mississippi (Gilbreath & Henry, 1998). Wolf bounties were awarded in North Carolina in the late 1700's and red wolves were eradicated from the state by the late 1800's (Barclay, 2002; Mech & American Museum of Natural History, 1970; Webster, et al., 1985). In 1967, they were designated as endangered and became one of the first species listed under the U.S. Endangered Species Act (ESA) (Hinton, et al., 2013). They were reintroduced into northeastern North Carolina (NENC) in 1987 but their populations grew slowly and then diminished again recently, mainly being threatened by high rates of poaching (Hinton et al., 2016b). Critical to their survival will be revealing the psycho-social, political, attitudinal, and behavioral mechanisms leading to poaching (illegal killing), part of which this research will investigate. Many authorities believe that tolerance of landowners is a prerequisite for protection of critically endangered species, especially where protected areas are small or laws against killing wildlife are poorly enforced. Landowner attitudes might be particularly important where poaching is done by outsiders, or by a few residents, and their peers turn a blind eye.

1.1 Poaching is the major threat to wolves

Poaching is a major component of anthropogenic mortality in many carnivore populations (Treves et al., 2017a; Woodroffe and Ginsberg, 1998; Wydeven et al., 2001). We define poaching as any non-permitted, intentional or unintentional killing of an animal, including behaviors such as shooting, poisoning, trapping, etc., even if the target animal was other than a red wolf (Treves et al., 2017c). As a percent of all mortality, poaching accounts for 24 – 75% of large carnivore deaths for different species globally (Chapron et al., 2008; Treves et al., 2015). Fifty-one percent of wolf mortalities in Scandinavia over the last decade were the result of poaching, with 69% of those having evidence concealed by poachers (Liberg et al., 2012). In Wisconsin, poaching accounted for 39% - 45% of all radio-collared wolf mortality over three decades with an estimated 50% of the poaching cryptic, but this number is believed to be an underestimate because of non-reporting and uncertainty about non-radio-collared wolf mortality patterns (Treves et al., 2017b)(Treves et al., 2017c). Red wolves are no exception.

For the first 25 years after reintroduction of red wolves, 57% of all observed deaths including adults, pups, radiocollared and non-radiocollared (or 72% of red wolves with a known cause of death) were human-caused with 30% of these from illegal activities including poisoning and gunshot, 3.5% from private trapping, 5.0% management, 20% vehicle, and 19% unknown. The remaining were natural causes including 6.5% intraspecific competition, and 16% health-related causes (Bartel and Rabon, 2013). However, these percentages obscure that the 19% of animals whose fates were unknown did NOT die of legal cause and probably not from causes that are readily reported. Rather the majority represent poaching presumably followed by destruction of telemetry equipment on the wolf. Treves et al. (2017a) corrected such estimates of mortality risks over a longer period using known and unknown fates of telemetered adult red wolves to estimate 44–72% risk from poaching and lower risk of legal killing. Agan et al. (2020)

estimated risk for poaching to be 51-63% for red wolves. The Red Wolf Species Status Assessment (SSA), US Fish and Wildlife Service (USFWS), Rivenbark et al. (2018), and Hinton et al. (2016b) all report that gunshots were the most frequent cause of death for wild red wolves. Most of these deaths happened during the autumn and winter hunting season which coincided with red wolf pair formation (Hinton et al., 2015). This disrupted wolf reproduction, increased hybridization with encroaching coyotes *C. latrans,* and sometimes resulted in loss of entire litters (Hinton et al., 2015). Hunters seemed more likely to have opportunistic encounters with red wolves than the average citizen and red wolf gunshot mortalities during fall and winter hunting season (deer, black bear, waterfowl) have increased dramatically since 2000 (Hinton et al., 2016b). The USFWS identified intolerance as a threat to wolf populations and it appears as though high rates of poaching are committed by a few persons who dislike wolves (Bruskotter et al., 2014). The USFWS acknowledged the "success of wolf conservation depends on public policy, human behavior and attitudes" (Bruskotter and Wilson, 2014). Tolerance for red wolves and their conservation has also been described as acceptance, believed to be an important aspect of the success of wildlife management programs for species such as red wolves and bears (Jørgensen, 2013; Zajac et al., 2012) and poor public acceptance is one of the main reasons for failure of such predator reintroduction programs (Clark, 2009). In their most recent 5-year review, the USFWS also stated, "Due to the importance of private lands to red wolf conservation (over 90% private land ownership in the Southeast), socio-political factors are as important if not more important than ecological factors" (Weller, 2018) echoing Treves and Karanth (2003) for large carnivores globally.

Poaching of carnivores is still not well understood for carnivores generally (Browne-Nuñez et al., 2015; Carter et al., 2017; Treves and Bruskotter, 2014) and is often underestimated

(Chapron and Treves, 2016; Liberg et al., 2012; Treves et al., 2017a, 2017c), because of cryptic poaching, when poachers conceal evidence, typically by destroying radio-transmitters. Concealment of evidence and the difficulty of surveying those who act illegally (St John et al., 2011) inhibits our understanding of effective policy and management interventions (Browne-Nuñez et al., 2015; Treves & Bruskotter, 2014). Attitude surveys are a primary tool for assessing perceptions of natural resources including wolves (Manfredo, 2008). However few surveys have addressed tolerance as it is currently defined; "tolerance consists of individual's judgments and behaviors toward carnivores" (Treves & Bruskotter, 2014). There has also been little consistency in the measurement of attitudes toward large carnivores (Bruskotter and Wilson, 2014) and an absence of rigorous theoretical approaches (Vaske and Manfredo, 2012).

Ericsson & Heberlein's (2003) study of wolves returning in Sweden examines a system very similar to the history of red wolves returning to the wild in NC. In Sweden, wolves had been functionally extinct until a pair appeared in the late 1970's and the population began to grow throughout the 1990's. With wolves still well below carrying capacity, local people's attitudes began to change as their knowledge and experience with wolves increased. This change was most profound among local residents and hunters who became more negative towards wolves. However, attitude did not always correlate with knowledge and experience, which means it may be influenced by other personal characteristics. Their study along with others show socioeconomic characteristics such as age, gender, education, and residence, among others influence attitude toward wolves (Ericsson & Heberlein, 2003). Longitudinal measures such as Treves et al. (2013) and Hogberg et al. (2015) increase understanding of individual changes in tolerance sampled repeatedly as they experience external and internal forces, while cross-sectional studies such as Ericsson & Heberlein (2003) and Bruskotter et al. (2007) increases our understanding of sociodemographic changes in attitude across a larger number of individuals sampled once.

Previous studies have concluded that the social and political aspects of red wolf recovery, in particular for landowners and hunters within the five county red wolf recovery area (Dare, Hyde, Tyrrell, Beaufort, Washington), have been overlooked (Serenari et al., 2018; Vaughan et al., 2011). Landowners experience the effects of policy changes more than those who don't live in wolf areas. The original Red Wolf Recovery Plan included the goal of "removing threats that have the potential to bring about extinction of the species" (US Fish & Wildlife Service, 1982). However, in 1994, the General Assembly of NC passed House Bill 2006 allowing landowners to use lethal means to take wolves on their property, after which four wolves were shot illegally in one year (Gilbreath and Henry, 1998).

The most recent policy changes proposed by the USFWS on August 13, 2018 would replace the current regulations governing the Nonessential experimental population (NEP) of red wolves, which were codified in 1995 (Kurth, 2018). The new rule would "remove management efforts from existing private lands and instead focus continuing efforts on certain public lands in Hyde and Dare counties, North Carolina" (Kloer, 2018) (Fig 1). This change would ultimately allow killing of red wolves on all private land. This proposal comes right after the release of the 5-year review in April 2018 in which they recommended no change in the endangered status of the red wolf. However they did state they were considering new management options due to the conditions created by human-caused mortality such as breeding pair disbandment and hybridization with coyotes and added that, "maintaining a small and more manageable wild population remains important to fostering the species in the wild" (Weller, 2018).

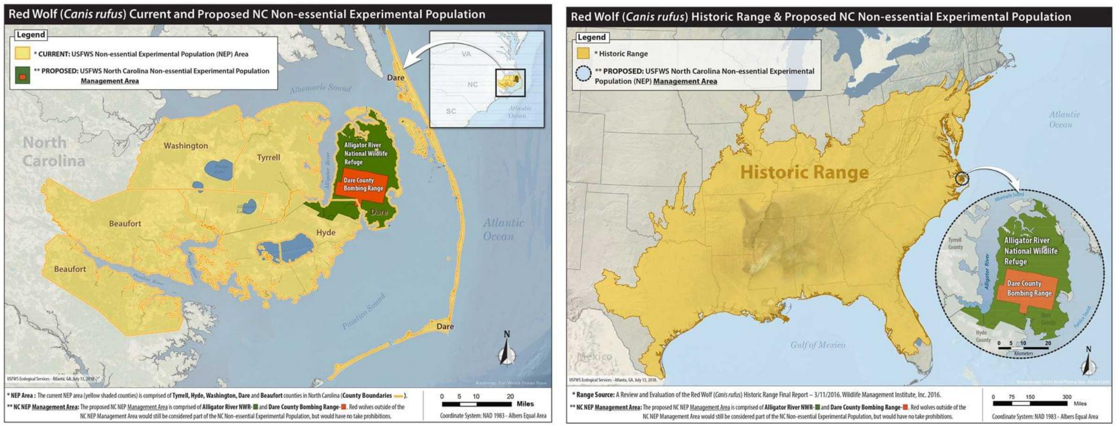

Fig 1. a) Red wolf current and proposed NC Non-essential Experimental Population, based on the new proposed rule. b) Red wolf historic range and proposed NC Non-essential Experimental Population (USFWS, n.d.)

For red wolves, we need to understand the social, psychological, and political mechanisms that lead to poaching in NENC and threaten the persistence of the last wild population of the red wolf. To understand poaching of red wolves better and perhaps intervene against it, we need more information on the perpetrators, those who turn a blind eye, and tolerance of the broader community for red wolves and for poaching. We report on measures of attitudes and intentions from surveys of two pools of respondents in and around the red wolf recovery area (RWRA) (Fig 2) with the goal of identifying individuals who tolerate wolves or not, describe the attributes of those who might poach red wolves, and to estimate the frequency of such individuals. Before describing our methods, we present a theoretical framework for the use of attitudinal surveys as a first step in anti-poaching interventions.

1.2 Illegal killing appears to be intentional

According to the ESA "take", which is illegal, is defined as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct" (United States, 1983). The 1987 amendments to the ESA do not define "knowingly" to include knowledge of an animals species or its protected status, rather it means the act was done voluntarily and intentionally and not because of a mistake or accident (Newcomer et al., 2011).

Wolf poaching appears to be intentional in the sense of the perpetrator meaning to kill an animal; by poisoning, trapping, or shooting, unlike vehicle collisions in which the driver likely does not intend to kill an animal (Treves, et al., 2017a) although vehicles may be involved in poaching too (Treves et al. 2017b). Rationalizations or reasons used by poachers show intentionality and may include negative disposition toward legal authority, disagreement with regulations, recreation, thrill killing, traditional rights or rebellion (Filteau, 2012; Muth, 1998). Poachers also justify their crimes by citing deficient knowledge of rules, unfairness in the system (Gore et al., 2013) or believe their behaviors and intentions were in the majority (St John et al., 2011). Incidents of poaching have also increased during times of political volatility (Gilbreath and Henry, 1998), and during periods of liberalized wolf killings (Treves, 2019). Such evidence corroborates the hypothesis that poaching is often an intentional action, not accidental. Given the legal definition of take that does not require knowledge of the endangered animal's identity or status as protected, we include within poaching those actions intended to kill any animal that result in death of a red wolf. Therefore, we use the theory of planned behavior and its later derivatives that address the combination of attitude, social norm, and perceived volitional control believed to affect the intention to act (Ajzen, 2011, 1985; Boslaugh, 2013; Browne-Nuñez et al., 2015). Ultimately actions are lower, motor-level implications of higher-level cognitive processes (Juarrero, 1999), so we hope to understand poaching and intervene against it by understanding its cognitive precursors reported in surveys.

1.3 Theoretical Framework: Planned Behavior, Cognitive Hierarchy, & Routine Activity

Intentional behaviors, such as poaching, are theorized to result from emotional or cognitive processes of the individual and affected by external forces: social norms of behavior that are partly external and partly perceived by the actor, and by the opportunity to act (Carter et al., 2017; Treves & Bruskotter, 2014). There are several theories that we used in this study related to attitudes, and how they develop and lead to behaviors such as poaching. The Theory of Planned Behavior (TPB), Cognitive Hierarchy Theory (CHT), and Routine Activity Theory (RAT) can be used to develop a theoretical framework that can be applied to red wolf poaching. We combine these theories to inform questions we would ask in our interviews and surveys as well as thinking about our analysis of psycho-social, political, attitudinal, and behavioral mechanisms.

TPB predicts an individual's intentions to perform a behavior, which is a function of their attitude, subjective norms and perceived behavioral control (PBC) (Ajzen, 1985). TPB has been used extensively to understand motivations and behaviors towards large carnivores including wolves in Europe (Johansson et al., 2016), leopards in India (Jhamvar-Shingote and Schuett, 2013), jaguars in Brazil (Marchini et al. 2012), and tolerance of gray wolves in the United States (Browne-Nuñez, et al., 2015) . We have used this theory as the foundation of our framework to make hypotheses about the intention to poach.

We think that positive and negative attitudes toward wolves can help predict and influence behavioral intentions when those attitudes are specific enough (Manfredo and Dayer, 2004; Pierce et al., 2001). For most people, attitudes about wolves have developed indirectly through second-hand information, images and ideologies (Kaltenborn and Brainerd, 2016). These are usually more loosely held and less important attitudes, subject to change. However, when wolves return to the landscape after being absent for a long period of time, it is important to understand the role of direct experience when these large carnivores reappear since those living in wolf areas are expected to have more direct experience than those who do not (Ericsson and Heberlein, 2003). Around the world, those who live in wolf areas tend to have more negative attitudes toward wolves than the general public but experience with wolves in such cases is confounded with rural identities and economics (Bath, 1989; Kellert, 1990; Naughton-Treves et al., 2003; Treves & Martin, 2011). Yet, to date there is an unclear relationship between experience (including knowledge) and tolerance for wolves with research showing positive, negative and no correlation between the two (Biggs, 1988; Bjerke et al., 1998; Browne-Nuñez et al., 2015; Ericsson & Heberlein, 2003).

At the societal level, negative attitudes can increase resistance to public policy regarding wolf recovery (Bruskotter & Fulton, 2012; Dressel et al., 2015; Houston et al., 2010). On an individual level, negative attitudes can lead to poaching (Browne-Nuñez et al., 2015).

Another aspect of TPB, social factors such as peer group norms influence intention to poach (Marchini & Macdonald, 2012) and can change support for wolves (Johansson et al., 2016). In Wisconsin, bear hunters believed those in their group, who shared the same social norms, generally sanctioned illegal killing of wolves (Browne-Nuñez et al., 2015) . Bear hunters had the lowest tolerance for wolves (Naughton-Treves et al., 2003) and the highest inclination to poach wolves (Treves et al., 2013) albeit not the greatest opportunity to do so (Treves et al., 2017b). If we want to understand red wolf poaching, we need similar data on social norms and group identification in the red wolf recovery area as related to the inclination to poach.

If we find evidence that deep-seated values are being invoked by our respondents, then the theory of cognitive hierarchy may prove useful for future research because it suggests that values are usually formed early and so they are tied to our identity, have strong emotional components and are resistant to change (Heberlein, 2012). Bright and Manfredo (1996) found that attitudes, about wolf reintroduction in particular, were based on values and emotions more than knowledge and beliefs.

Finally, Routine Activity Theory (RAT) has been used to address poaching problems in the US (Eliason, 2012; Treves, et al., 2017b) with regards to opportunity. With actual control over a behavior, people are expected to carry out their intentions when the opportunity arises; opportunity consisting of motivation, a suitable target, and lack of guardianship (Ajzen, 2011; Eliason, 2012). Treves et al. (2017b) used the general framework of TPB and RAT and applies it to wolf-human interactions leading to the potential to poach. We have used this theory to address the issue of opportunity in NC where potential poachers encounter red wolves and law enforcement is absent such as on private lands. Therefore, we surveyed landowners as part of our sample of the general populace of NENC and included questions concerning opportunity such as hunting.

1.4 Advocacy

Ethics are also a part of the discourse concerning the relationship between humans and wolves (Lynn, 2010) and can be seen in part through advocacy. The last twenty years has seen an increase in advocacy for animal rights/welfare with support for extending moral rights to animals and is correlated with a more romantic view of nature (Kruse, 1999). Women are more likely to be animal rights advocates (68-80%) (Herzog Jr et al., 1991; Kellert and Berry, 1987; Peek et al., 1996), are the majority of animal welfare organization memberships (DeMello, 2012; Kruse, 1999) and make up 80% of volunteers and workers in animal protection (Munro, 2001). This includes women who are hunters (Gamborg and Jensen, 2016). In interviews with eastern North Carolina women hunters, 92% viewed hunting as a wildlife strategy and all participants emphasized the importance of caring for animals in the wild (Bragg-Holtfreter, 2017; Coleman, 2008). The number of women who are hunters in NC has increased by 25% since 2006, and at the same time concern for animal welfare has increased, making women hunters an important component to understand human-animal relationships (Bragg-Holtfreter, 2017).

Gender has emerged as the most significant factor in some of those attitudes including animal exploitation (Luke, 2007). Luke (2007) goes so far as to say that sexist ideology has men believing they must dominate other living things to be men. Of course this is a more extreme view and culture is shifting, at least in some areas, to change gender roles of both men and women, which could have effects on how they relate to animals (Rudy, 2008). Manfredo (2009) reported a population-level shift from domination to mutualism wildlife orientations in North America.

With advocacy changing, we may see more and stronger advocates for animals in the younger generation. Generational theory says that people tend to reflect some of their environment (Bryan, 2008) and so as the environment changes, we would expect people to change with it. Individuals born in a particular time-frame are exposed to a unique mix of environmental factors forming attitudes and behaviors (Firkins, 2017). The current millennial eneration has been described as more socially liberal, educated, and racially and ethnically diverse (Frey, 2018). Both age and gender have emerged as important to animal advocacy, which may be reflective in their attitudes and behaviors toward wolves.

1.5 Purpose

We had 4 goals related to respondents' stated views on red wolves, poaching, and protection. (1) We measured attitudes of landowners and hunters, and residents compared to non-residents of NENC from surrounding areas. Landowners and those in certain peer groups, e.g., hunters have opportunity to poach or protect red wolves, and social norms might be particularly important if hunting is a social activity conducted in isolation from outgroup members. Given recent attention and concern about the causes and consequences of wolf-poaching, we aim to measure cognitive antecedents to poaching of red wolves. This might help in anti-poaching efforts or other policy design challenges for this critically endangered species. (2) The TPB expects a correlation between attitude to red wolves and intention to kill them, social norms relating to red wolf protection or killing and intention to kill them, and also between opportunity to encounter red wolves and intention to kill them. Our goal in this case is to quantify each correlation, compare one to the other and if possible, generate a specific, predictive model of the constellation of responses that characterize the individuals with a stated intention to poach red wolves. (3) We examine the RAT and recent ideas on opportunity for both would-be poachers and those who might kill a red wolf as a non-target animal (e.g., coyote hunters who express no intention to kill a red wolf). (4) To understand resistance or support for the ESA and its prohibition on take, we will explore the relationships between attitude toward red wolves, support for their conservation, trust of the USFWS, and attitude toward current policy (we collectively define as acceptance). To achieve our objectives, we qualitatively and quantitatively explore attitudes and behavioral inclinations using mixed-methods research.

2. Materials and Methods

2.1 Study site

Our nine-county study site consists of the five counties within the RWRA on the Albemarle Peninsula in NENC (Beaufort, Dare, Hyde, Tyrrell, and Washington counties) and all four directly adjacent counties (Pitt, Craven, Pamlico, and Martin counties). Total human population for all nine counties according to the North Carolina 2017 estimated census was 421,712, the lowest population density for the state ("Population density of NC 2015," 2015). The population consists of 49.06% males and 50.93% females and has median age of 45.97 ("NC

OSBM: LINC," retrieved 4/1/2019). The RWRA includes four USFWS managed National Wildlife Refuges: Alligator River, Mattamuskeet, Pocosin Lakes, and Swanquarter, a Department of Defense bombing range and state-owned lands (Fig 2). Together, federal, state, and private lands in the RWRA cover approximately 6,000 km^2.

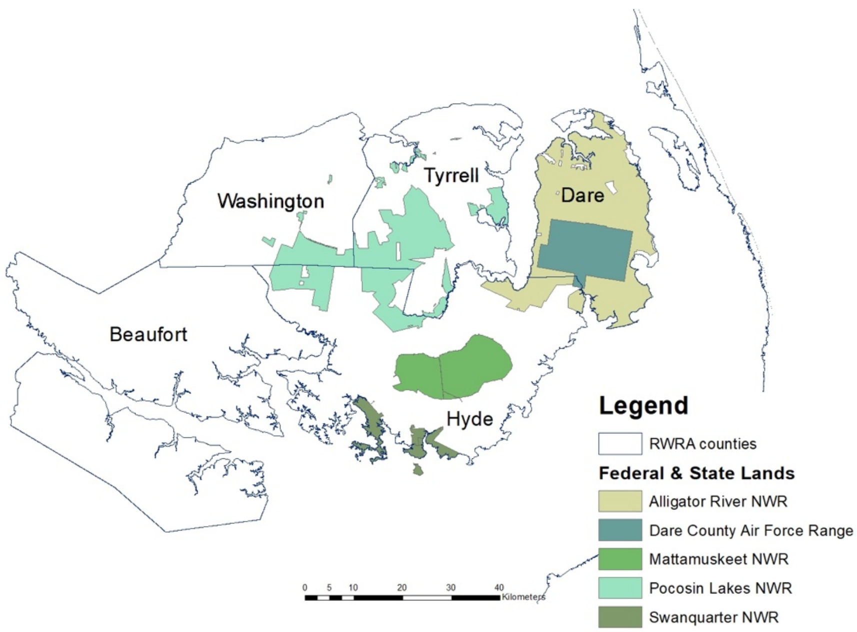

Fig 2. Red wolf recovery area showing federal and state-owned lands

During spring and summer, agricultural crops comprise 30% of vegetation on the peninsula, and these areas are barren through fall and winter. The identification of agricultural areas is particularly important for our study as red wolves use these areas more than what has been documented in other wolf studies (Mladenoff et al., 2009; Treves et al., 2009). This also increases the potential for interactions between wolves and humans (Hinton et al., 2016a) and increases opportunities for poaching. The remainder of the primary habitat types consists of coastal bottomland forest, and pine forest.

Mixed methods research has been increasingly used in recent years, especially applied to social science and sensitive topics (Wutich et al., 2010). Sensitive topics include those that have threats and costs to participants including private experiences and socially unacceptable attitudes or actions. Because our study asks questions about illegally killing red wolves, we used in-depth interviews of selected key informants and anonymous surveys to limit risk to participants. In criminal justice research, self-administered internet surveys have reported double the amount of crime over those administered through an interview (Pepper et al., 2003) and so our anonymous survey should increase accuracy of reports about poaching behaviors, allowing us to identify would-be poachers of both types (those with access who would not knowingly kill a red wolf and those who would knowingly kill one). The most common mixed methods study design combines questionnaire and interview data, and a recent report of technology applications for social research found that 57% of social science studies employ this method (Fielding, 2012). In this study, we chose a mixed methods approach for development purposes (qualitative interviews to inform quantitative survey questions), and for triangulation (validating results) (Lapan and Quartaroli, 2009).

2.2 Interviews and Survey Instrument

Before developing our survey instrument, we conducted seven interviews with landowners in the RWRA. Initially SA interviewed two landowners to simply listen to their stories regarding red wolves and gain an understanding of how red wolf recovery is viewed by landowners, informing questions we should ask in later interviews. Then we conducted semi-structured interviews with an additional five landowners to inform our final survey instrument.

We used several resources to find contact information for landowners for the interviews, as we wanted a diversity of experience and attitudes at this stage. Resources included online agriculture databases, hunting websites, USFWS personnel's recommendations, and online public tax assessors' databases. We interviewed landowners who owned more than 4 ha (10 acres) and who had lived in the RWRA for the entire 30-year period of red wolf reintroduction. For the five semi-structured interviews, our questions focused on how their attitudes have developed over time since reintroduction, if at all, what had influenced their attitudes (media, social institutions, politics, USFWS personnel, etc.), how policy affects their behavior (to poach or not to poach), where hunting clients are travelling from if the respondent owned hunting leases, and the landowner's experience with red wolves.

Because our goal was to understand the relationships between attitude and illegal killing, we also hoped to interview any self-identified poachers to learn their motivations and rationales to poach, and what interventions would prevent them from poaching. Among our seven interviews, one self-identified as a red wolf poacher.

During each interview, SA solicited feedback about questions the respondents believed we should be asking, and SA modified the interviews iteratively. We audio-recorded interviews, which a transcription service transcribed, and SA reviewed for accuracy. We then triangulated the transcriptions, again for accuracy, by comparing them to field notes written during and immediately after the interviews. SA analyzed data from the interviews with NVivo software using thematic analysis and coding. She then sorted codes into categories and into overall themes as those categories appeared (Table 1).

Table 1. Themes and categories from Fall 2018 interviews

Theme	**Categories**
Government	Property rights, Communication, Policy, flooding, NGO's, individual influence
Culture	Hunting, Belonging, experience, outsiders
Red wolves	Reintroduction, Poaching, NIMBY, Native status, Experience
Wildlife Management	Coyotes, Black bears, Deer
Economics	Taxes, Farming, Hunting leases, value of red wolf
Communication	Education (coyotes, hybridization), Why? (benefits, concerns), Media

From these interviews combined with previously used survey instruments from similar attitude studies in carnivore research (Browne-Nuñez, et al., 2015), we developed an 18-question online survey. We designed it to measure respondents' experiences with red wolves, attitudes and behavioral inclination toward them, attitudes to the USFWS and red wolf recovery, and to measure experience with red wolves, and collect demographic (age and gender) and location (county and zip code) information about respondents.

2.3 Quantitative Data collection

Our target population for the survey was adults over the age of 18 who lived or owned land in the study area. We wanted a diverse pool of respondents, therefore we used two different methods of sampling: a pre-recruited panel (probability sample) and an anonymous survey link (convenience sample), distributed by email and internet respectively. We chose these methods because telephone surveys are no longer the best option due to low social acceptance along with other limitations (Yeager et al., 2011), and mail surveys were unaffordable for this project.

Both of these methods have limitations and bias. Key problems with pre-recruited panels include low initial response rates, gender bias and internet usage bias (McKenna et al., 2007). With a low rate of recruitment, people agree to participate in probability panels only 1-18% in some studies (McKenna et al., 2007). There are also multiple stages of recruitment from first contact, to being a member of a panel, to final contact for a survey, with a cumulative average response of only 10-20% (Hays et al., 2015; Tourangeau et al., 2013). Although they may start out as representative, nonresponse may introduce bias. Women are much more likely than men to sign up, as are those who use the internet on a more regular basis (McKenna et al., 2007). Those who use the internet more often are more likely to complete a survey first, leaving out those who use it less and there are differences in attitude measures between those who have internet access and the full population (Tourangeau et al., n.d.). Convenience samples also are likely to be biased and therefore unrepresentative (Tourangeau et al., 2013). It was our goal therefore, to recruit as diverse a response-base as possible by using both types of samples.

We selected Qualtrics Experience Management® (Qualtrics), a global data management company, for our probability sample. Qualtrics offers a research panel to recruit a guaranteed number of survey participants and guaranteed 250 respondents for our nine-county study area. They provided a cash incentive of $8 US for each respondent. Incentives increase response rates, lower nonresponse error and encourage trust that the study is important (Dillman et al., 2014). The Qualtrics panel is designed to be statistically representative of the US population. Qualtrics states, "each sample from the panel base is proportioned to the general population and then randomized before the survey is deployed." Respondents are invited to participate in the survey by email and to avoid self-selection bias, the survey invitation does not include the topic of the survey (Qualtrics ESOMAR 28, n.d.). Probability sampling such as this has been shown to be more representative of the population's demographics (Chang and Krosnick, 2009), however our Qualtrics panel, while randomly sampled, was not representative of the study site (see below). The company stated that it is more difficult to achieve a representative sample for smaller study sites such as ours due to a smaller pool of respondents to recruit. Qualtrics was unable to provide data regarding follow-up or surveys that were open but not completed.

On October 30, 2018 Qualtrics contacted an unknown number of individuals on its panel with the survey link and received a total of 288 complete responses. The ability to recruit respondents is a bit lower than previous surveys of Wisconsin residents on wolf policy that included a cash incentive with a mail-back questionnaire design (Hogberg et al., 2016; Naughton-Treves et al., 2003; Shelley et al., 2011; Treves et al., 2013). We did not evaluate nonresponse bias since we were not able to determine how many were initially contacted and respondents' identities were kept confidential by Qualtrics.

Second, for our complementary convenience sample, we purchased 100 037 email addresses from National Data Group (NDG), which maintains a database containing age, and physical addresses including zip codes so we were able to constrain our emails to respondents over the age of 18 and also geographically to those zip codes in our study area. From October 30-November 30, 2018, SA sent an email to those addresses with the link to the same instrument described above for the Qualtrics panel with an email reminder one week later. Those emails were not managed by Qualtrics, only hosted through their platform. Out of the initial 100 037 emails, 82 128 were never opened, 17 280 were undeliverable, 445 surveys were started and 112 were completed. We had no way to track how the anonymous survey link was forwarded to others and so how many people were reached is unknown.

Dillman et al. (2014) recommend several strategies to increase response and decrease nonresponse error including using multiple contact methods, delivery methods, shorter survey instruments, incentives, and follow-up requests (Dillman et al., 2014). We expected self-selection bias to be high in the convenience sample as we would expect salience to have a positive effect on response rate, biasing responses towards extremes and fewer 'don't know' responses (Dillman et al., 2014). We also expected salience of our survey to be low for the probability sample, because those respondents would probably have low knowledge, interest, or experience with red wolves. Therefore, we expected many neutral or 'don't know' responses from our probability sample. We believe our two pools of samples complement each other in terms of salience, while perhaps diverging in terms of demographics. The probability sample may be more representative of the general populace whereas the convenience sample might predict how public meetings about red wolves and public comments on policy would appear.

We decided not to weight our data because post-stratification can adjust bias differences but never completely, typically removing less than half the bias (Tourangeau et al., 2013). If an original unadjusted estimate produces a small bias, adjusting can sometimes significantly increase the amount of bias (Tourangeau et al., 2013).

To evaluate the potential differences between the two samples, we compared demographic information (gender, age and location) for each using Chi-squared and one-sample t-tests comparing each sample to the overall population of our study site. We collected overall age and gender data for our study site from the NC State Demographer LINC system, 2017 population estimates ("NC OSBM: LINC," n.d.). We also used hunting licenses registered with the state of North Carolina to compare the percentage of hunters in each county from the survey.

2.4 Response

Through the two survey distribution methods, the response was n = 1883 (1438 probability and 445 convenience) individuals. Surveys that were started but were not filled out in their entirety (n = 1467) were not used in this study to improve the quality of data (Hays et al., 2015). Of those 1467 incomplete surveys, all respondents were disqualified either because they identified as living outside our study site or were under the age of 18. In each of these situations, their survey automatically ended after that choice and no further data was collected. An additional 16 complete responses were disqualified as speeders (those who completed the survey quicker than was determined to be appropriate by Qualtrics for valid responses). The remaining 400 complete responses used for analysis consisted of 288 from the probability sample and 112 from the convenience sample.

2.5 Survey Measurements

Survey respondents were asked about their identity into social groups relevant to wolf issues, “To what extent would you include yourself with each of the following groups”, (Bruskotter et al., 2018; Slagle et al., 2019) of wildlife advocate, animal welfare advocate, hunter, conservation advocate, gun rights advocate, environmental advocate, farmer (crops), rancher (animals), and property rights advocate. Response choices were “strongly”, “moderately”, “slightly”, and “not at all”. We combined those who identified as “strongly” and “moderately” into identifiers and those who selected “slightly” or “not at all” as non-identifiers. This was assessed qualitatively using the same method as Bruskotter (2018) by looking for similarities in how respondents with different identification choices responded to behavioral inclination questions.

We measured atitude using three items. Question 8 asked, “How would you describe your general attitude toward red wolves?”. Responses consisted of a seven-point Likert-style scale ranging from “strongly like” (7), to “strongly dislike” (1) with “neutral” (4) and “I don’t know” which was not included in the numeric scale. For some analyses, this question was reduced to a scale of 0 (“strongly dislike”, “dislike”, “slightly dislike”), 1 (neutral), and 2 (“strongly like”, “like”, and “slightly like”) for simplicity and to compare with other attitude questions that used the same scale. Question 12 asked respondents to “please state your level of support for conserving red wolves” as “support” (2), “neutral” (1), “oppose” (0), or “I don’t know enough”, which was not included in the numeric scale. Question 15 stated, “The US Fish and Wildlife Service proposes that wolves outside of the new (non-essential experimental population, NEP) management area would remain part of the NEP but take of these animals on non-federal lands would be allowed”, and asked whether respondents “liked” (2), were “neutral” (1), or “disliked”

(0) the policy, or “don’t know enough to decide”, which was not included in the numeric scale. We provided no further explanation of the policy from the USFWS nor were they provided a map of the NEP. We interpret a favorable response to this policy as an unfavorable attitude toward red wolves because this policy allows for more freedom to kill red wolves.

We combined four questions to create a multi-item scale variable encoding acceptance for the red wolf recovery program (Fig 3). These four questions refer to measures of attitude, support, and trust, which we believe are all part of acceptance. Other studies have also connected variables such as attitude, experience and management to acceptance (Balčiauskas and Kazlauskas, 2014). Following the methods of Treves et al. (2013) and Hogberg et al. (2016) we measured acceptance as a simple sum of the three responses (Q8, Q12, Q17) that are positively correlated with acceptance and subtracted the one response that was negatively correlated (Q15). For this variable we changed the scale of Q8 from 1-7 to 0-2, so that all four variables were equally represented.

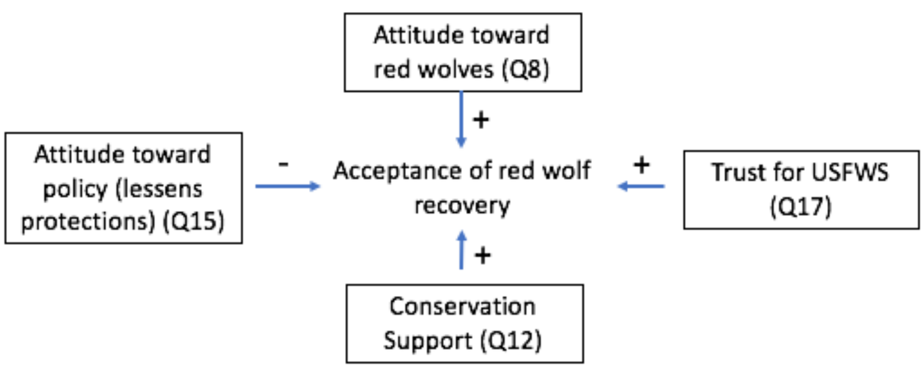

Fig 3. Conceptual model illustrating the four variables we combined to create an index of acceptance of red wolf recovery.
Signs (+/-) show how responses were added or subtracted from the total.

We measured experience as a composite index of 10 items, which respondents identified by checking all of the following they had experienced: 1) “no experience”, 2) “seen a red wolf in the wild”, 3) “heard a red wolf in the wild”, 4) “discussed red wolves with USFWS personnel”,

5) “read or heard about red wolves in the news”, 6) “attended red wolf informational meeting”, 7) “seen an educational display for red wolves”, 8) “visited a red wolf howling event at Alligator River National Wildlife Refuge (ARNWR)”, 9) “conducted your own research on red wolves through internet searches, reading books, watching documentaries or other media”, 10) “other”. The composite assigned zero to ‘no experience’ and one point to every other response, for a total possible score of 9. This question does not consider how many times a respondent has had any of these experiences and so higher values represent more types of experience only, not total amount of experience. We used the composite index of experience as a predictor (independent) variable in models for attitude and behavioral inclination with the consideration that a more diverse set of experiences may correlate with those responses. Previous research on wolf attitudes have shown both direct (Williams et al., 2002) and indirect experience (Karlsson and Sjöström, 2007) can influence attitudes toward wolves (Ericsson and Heberlein, 2003; Williams et al., 2002) and so we use items 2) “seen a red wolf in the wild”, and 3) “heard a red wolf in the wild” to ask about direct experience by our participants.

We measured behavioral inclination using two items (Q11 and Q14) summed for a range of possible values from 0–9. Question 11 asked, “It’s currently against the law for a private citizen to kill a red wolf except in defense of life (human, livestock, or pets). Are there any other situations you might try to kill a red wolf anyway?” adapted from (Browne-Nuñez et al., 2015). Options included (1) “any wolf I encounter on my own”, 2) “the wolf did not run away from me when I was on foot”, 3) “the wolf did not run away from my vehicle”, 4) “the wolf was on my property”, 5) “the wolf came too close to my home”, 6) “the wolf approached my pet or farm animals”, 7) “I would not kill a red wolf”, 8) “I would support someone else killing a red wolf”, and 9) “other”. If the latter indicated a situation in which the respondent would kill a wolf, we scored it as a one and added one point for each and every response other than (7), which scored zero. Therefore Question 11 ranged from 0–8. We then summed that with the result of question 14 which asked, “What would you do if you saw a red wolf on your property?” Choices included 1) “I would try to protect it”, 2) “I would watch it”, 3) “I don’t know”, 4) “I would call the authorities”, 5) “I would try to kill it”, 6) “I would try to scare it away”, 7) “I would ignore it”, and 8) “other”. We counted each response to Q14 as “non-lethal” (zero), but for response (5) which added one to the sum of Q11 above to make our composite score with a potential maximum score of 9. We used the remaining responses for Q14 to determine what other behaviors respondents might choose when they see a red wolf on their property that are correlated with other lethal and nonlethal choices and whether or not they choose to take actions into their own hands. We omitted Q14 response (3) from the index but considered it in discussion of salience. We used the behavioral inclination index as a response (dependent) variable. We also evaluated each behavior response individually as they might relate to attitude and demographic variables.

2.6 Analysis

We separated each item or composite (attitude, acceptance, experience, and behavioral inclination), and analyzed differences in demographics and property size since red wolves have used private property, and larger tracts of land may be more likely to host red wolves and have an opportunity to partner with the USFWS for conservation (USFWS personal communication). For analysis we grouped property size into 1) < 0.4 ha (one acre) and 2) ≥ 0.4 ha because there were fewer respondents with > 4 ha (10 acres) and this division gives us the most even split for our respondents. Because our two samples were different demographically, we present all data for each sample separately and when appropriate jointly.

Finally, we analyzed differences in attitude, acceptance, experience, and behavioral inclination by comparing hunters vs. non-hunters, farmers (crops) vs. non-farmers, and those who live in the RWRA (residents) vs. those who do not (non-residents). Hunters and farmers are not mutually exclusive groups as respondents could identify as both, however they were treated separately for analysis. We did not analyze ranchers (animals) separately as there were only a few individuals who did not also identify as farmers and there were no differences in attitudes, behavioral inclination or group advocacy for those who identified as only ranchers compared to those who identified in both groups.

After attitude, acceptance, experience, and behavioral inclination metrics were compiled as described above, the medians for each variable were calculated for all responses, for both samples. Median comparison tests were performed between the two samples and within stakeholder groups using the nonparametric Two-sample Wilcoxon rank-sum (Mann-Whitney) test and χ^2 analysis for binary variables such as individual experiences and behaviors. We tested for differences in socioeconomic characteristics of age and gender using χ^2 analysis. Correlations between red wolf attitude and experience with red wolves; experience and behavioral inclination; and attitude and behavioral inclination were assessed using Spearman's rank correlation to summarize the strength and direction of the relationship.

The spatial distribution of attitude was visually assessed by mapping individual attitude scores by zip code (provided by the respondent). We used STATA IC 15.1 for Mac (StataCorp, 2019), and R 3.5.1 (R Core Team, 2018) and set our alpha for significance to 0.05.

3. Results

3.1 Respondent Characteristics

Overall, the median age for respondents was younger than residents in NENC in general (39 and 43 y respectively), however the probability sample was younger with a median age of 33 and the convenience sample older at 54 y. Both the probability and convenience sample differed significantly from census in gender (Table 2) with more females in the probability sample and more males in the convenience sample.

The probability sample brought more responses from nonresidents (60% vs. 37% respectively) while the convenience sample brought more responses from residents of the RWRA (63% vs. 40%) ($\chi^2 = 17.8$, df = 1, P <0.001). The plurality of respondents reported owning <0.4 ha of land (41%) followed by 0.4-4 ha (33%), 4.1-40 ha (11%), 40.1-404 ha (6%) and more than 404.1 ha (1%).

Table 2. Characteristics of respondents in 2 samples and the census population for the 9-county study site

	Males	Females	χ^2	p	Median Age
Probability sample	78, 27%	203, 70%	42.8	<0.001	33
Convenience sample	67, 60%	41, 37%	9.5	0.002	54
All respondents	145, 36%	244, 61%	15.5	<0.001	39
Census population age >17y	156 066, 47%	174 232, 53%			43

*χ^2 is used to compare gender in each sample to the census, df=1.
*Totals for all respondents do not total 100% because 11 (2.8%) chose "prefer not to answer" for gender but are included in median age.

Hunters comprised 27% of the probability sample, 44% of the convenience sample, and 18% of all respondents reported using their land for hunting. The number of hunters from the survey were compared to the number of hunting licenses registered with the state of North Carolina from those counties. In our study, hunters are over-represented when compared with number of hunting licenses purchased in the state (32% of respondents vs. 11% of population), however, respondents could identify as a hunter even if they do not have an active hunting license (NC Wildlife Resources Commission, 2019). Our probability sample contained 25%

females and 35% males that identified as hunters. Our convenience sample contained 24% females and 54% males identifying as hunters.

We wanted to see how hunters identified in other groups we surveyed, especially wildlife advocates and conservation advocates (Table 3). Identifying as a hunter is significantly associated with five out of six of the other identities in the probability sample but only with gun rights and property rights advocates in the convenience sample.

Table 3. Group identification of hunters and farmers by sample.

Probability sample	**Hunters, n = 79**				**Farmers, n = 94**			
	n	**%**	χ^2	**p**	**n**	**%**	χ^2	**p**
Wildlife advocate	61	77.2%	9.625	0.002	78	83.0%	24.220	<0.001
Conservation advocate	58	73.4%	6.573	0.010	72	76.6%	13.499	<0.001
Animal welfare advocate	60	75.9%	4.827	0.028	78	83.0%	17.979	<0.001
Environmental advocate	54	68.4%	0.804	0.370	73	77.7%	10.945	0.001
Gun rights advocate	67	84.8%	42.067	<0.001	68	72.3%	19.259	<0.001
Property rights advocate	60	75.9%	21.450	<0.001	71	75.5%	26.469	<0.001
Convenience sample	**Hunters, n = 49**				**Farmers, n = 33**			
	n	**%**	χ^2	**p**	**n**	**%**	χ^2	**p**
Wildlife advocate	40	81.6%	0.490	0.490	33	100.0%	3.700	0.054
Conservation advocate	38	77.6%	0.840	0.360	27	81.8%	0.002	0.970
Animal welfare advocate	32	65.3%	1.600	0.210	27	81.8%	0.065	0.800
Environmental advocate	37	75.5%	1.420	0.230	25	75.8%	0.113	0.740
Gun rights advocate	44	89.8%	15.590	<0.001	31	93.9%	4.670	0.031
Property rights advocate	44	89.8%	7.380	0.007	34	103.0%	6.440	0.011

*all significant relationships, $p < 0.05$ are positively correlated, df = 1
% are out of total number (n) of hunters or farmers in each sample

Those who identified as farmers (crops) comprise 33% of both the probability and convenience sample. Farmers showed similar trends to hunters in identification with advocacy except the probability sample in which farmers were positively correlated for all 6 groups.

3.2 Attitude

3.2.1 Attitude toward red wolves

Most interviewees expressed being neutral about red wolves but had negative attitudes toward their reintroduction. Several expressed experiences of seeing or hearing wolves. Comments such as the following were common among those interviewed.

If you remove Fish and Wildlife, if you remove the endangered species classification, I don't know that I've got a big problem with them. If it's just if we're one-on-one, if we're standing on the same grounds, you're not protected any more than I'm protected, then I don't know that I've got a big issue.

During discussions, individuals expressed interest in hearing them howl, one called them "*pretty*", and another wished he could see them more but explained how they are too elusive. When asked about any problems, one farmer stated, "*I've not heard of a single incident where they caused any trouble*".

Among survey respondents in the probability and convenience samples 55% and 47% (respectively) reported positive attitudes (including "slightly like" and "strongly like") toward red wolves, 29% and 31% are neutral and 8% and 19% dislike red wolves (Fig 4). A Mann-Whitney median test indicated that attitude (using a 7-point Likert scale) toward red wolves was significantly more positive (Mdn = 6) for the probability sample than for the convenience sample (Mdn = 4) (z = -2.56, P = 0.011).

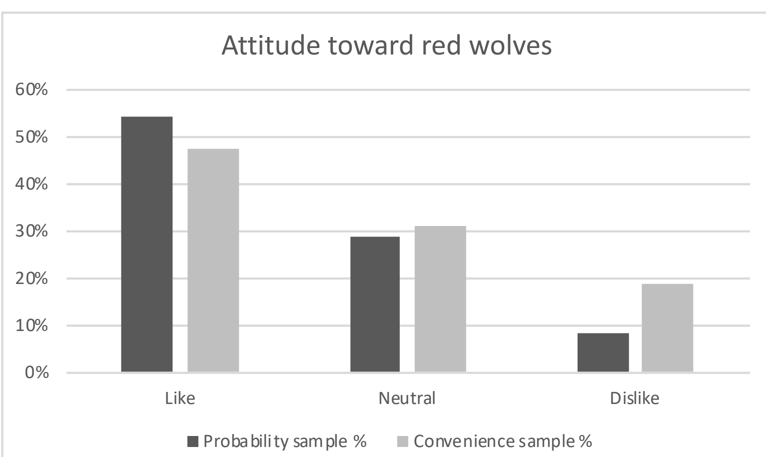

Fig 4. Attitude toward red wolves by sample, condensed from 7 to 3 categories.

There were no significant differences in attitude toward red wolves in any group for the probability sample (Table 4). Within the convenience sample, nonhunters were significantly more positive toward red wolves than hunters, and females more positive than males. However, with the two samples combined, nonresidents (n = 193) (Mdn = 5, IQR = 4-7) were significantly more positive toward red wolves than residents (n = 180) (Mdn = 5, IQR = 4-6) of the RWRA (z = 2.71, P = 0.007).

Table 4. Summary of median attitude survey responses used in our analysis by group.

		Probability Sample, n = 288					Convenience Sample, n = 112				
	Group	**n**	**%**	**Median**	**IQR**	**z, P**	**n**	**%**	**Median**	**IQR**	**z, P**
Attitude toward red wolves Q8	Hunters	76	26.39%	5.0	4-7	0.59, 0.555	48	42.86%	4.0	2-5.5	4.202, <0.001
	Non-hunters	188	65.28%	6.0	4-7		61	54.46%	6.0	4-6	
	Farmers	90	31.25%	6.0	4-7	-1.048, 0.295	37	33.04%	4.0	2-6	1.607, 0.108
	Non-farmers	174	60.42%	5.0	4-6		72	64.29%	5.0	4-6	
	Residents	110	38.19%	5.0	4-6	1.802, 0.072	70	62.50%	4.0	3-6	1.471, 0.141
	Non-residents	154	53.47%	6.0	4-7		39	34.82%	5.0	4-6	
	Males	74	25.69%	6.0	4-6	-0.216, 0.829	66	58.93%	4.0	3-6	-2.489, 0.013
	Females	184	63.89%	5.5	4-7		39	34.82%	6.0	4-6	
	I don't know	24	8.33%				3	2.68%			
Attitude toward conservation Q12	Hunters	66	22.92%	2.0	1-2	4.254, <0.001	44	39.29%	1.0	0-2	4.579, <0.001
	Non-hunters	150	52.08%	2.0	2-2		51	45.54%	2.0	2-2	
	Farmers	81	28.13%	2.0	1-2	1.675, 0.094	30	26.79%	1.0	0-2	2.199, 0.0279
	Non-farmers	135	46.88%	2.0	1-2		65	58.04%	2.0	1-2	
	Residents	83	28.82%	2.0	1-2	0.559, 0.576	65	58.04%	1.0	1-2	2.985, 0.003
	Non-residents	133	46.18%	2.0	1-2		30	26.79%	2.0	2-2	
	Males	67	23.26%	2.0	1-2	-1.66, 0.097	59	52.68%	1.0	1-2	-3.26, 0.001
	Females	145	50.35%	2.0	1-2		32	28.57%	2.0	2-2	
	I don't know	72	25.00%				17	15.18%			
Attitude toward policy Q15	Hunters	50	17.36%	1.5	1-2	-4.536, <0.001	34	30.36%	1.0	1-2	-3.577, <0.001
	Non-hunters	116	40.28%	1.0	0-1		32	28.57%	0.0	0-1	
	Farmers	61	21.18%	1.0	1-2	-3.624, <0.001	17	15.18%	2.0	1-2	-2.303, 0.021
	Non-farmers	105	36.46%	1.0	0-1		49	43.75%	1.0	0-2	
	Residents	60	20.83%	1.0	0-2	0.077, 0.939	42	37.50%	1.0	0-2	-0.657, 0.511
	Non-residents	106	36.81%	1.0	0-2		24	21.43%	0.5	0-2	
	Males	55	19.10%	1.0	0-2	0.846, 0.398	48	42.86%	1.0	0-2	2.274, 0.023
	Females	105	36.46%	1.0	0-2		14	12.50%	0.0	0-1	
	I don't know	122	42.36%				46	41.07%			
Trust in USFWS Q17	Hunters	70	24.31%	2.0	1-2	-0.764, 0.445	46	41.07%	2.0	1-2	-0.123, 0.902
	Non-hunters	154	53.47%	1.0	1-2		54	48.21%	2.0	1-2	
	Farmers	81	28.13%	2.0	1-2	-2.268, 0.023	36	32.14%	1.0	1-2	1.116, 0.264
	Non-farmers	143	49.65%	1.0	1-2		64	57.14%	2.0	1-2	
	Residents	93	32.29%	1.0	1-2	0.883, 0.378	66	58.93%	1.5	1-2	0.679, 0.497
	Non-residents	131	45.49%	2.0	1-2		34	30.36%	2.0	1-2	
	Males	69	23.96%	1.0	1-2	-0.408, 0.684	62	55.36%	1.0	1-2	-2.361, 0.018
	Females	150	52.08%	1.0	1-2		35	31.25%	2.0	1-2	
	I don't know	64	22.22%				12	10.71%			

Significance from Mann-Whitney test, p <0.05, indicated by shaded group.
Percentages do not include those who responded, “I don’t know”. Therefore % may total less than 100 within groups.
Q8 Attitude toward red wolves - Like (2), Neutral (1), Dislike (0)

Q12 Supporting conservation of red wolves - Support (2), Neutral (1), Oppose (0)
Q15 Supporting policy that allows killing of red wolves on private land - Like (2), Neutral (1), Dislike (0)
Q17 Trust of the USFWS - Trust (2), Neutral (1), Mistrust (0)

Visual assessment shows that areas further away from the current RWRA brought in more responses to our survey, which correlates with higher human population. While the three zip codes southwest of ARNWR have the most negative attitudes toward red wolves, these also represent areas with the fewest survey responses with only one response per zip code (Fig 5).

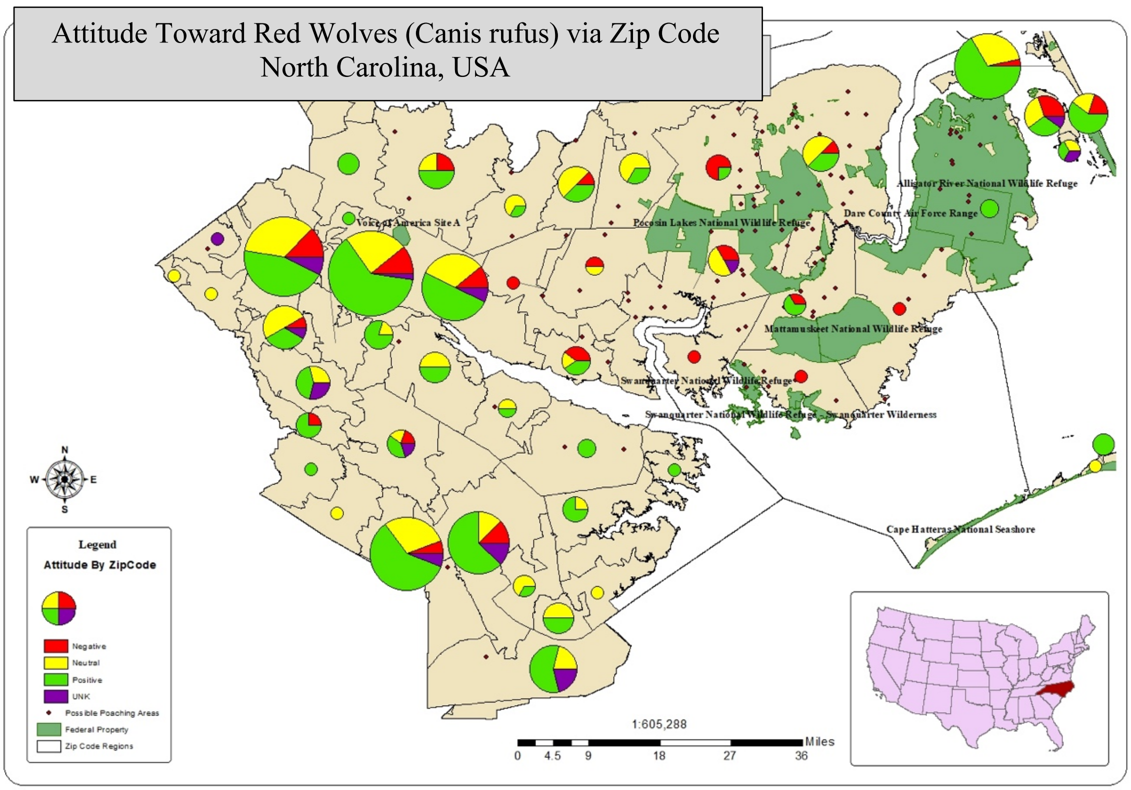

Fig 5. Red wolf attitude distributed by zip codes in the study area.
Attitudes range from like (2) to dislike (0) with 1 being neutral. Pie chart sizes represent numbers of survey responses in each zip code. Red wolf reintroductions began in Alligator River National Wildlife Refuge with green areas representing all federal lands within the RWRA.

3.2.2 Support for red wolf conservation

Every resident interviewed said they did not understand why red wolves were being reintroduced, nor why NENC was chosen as the reintroduction site. They also perceived that everyone they knew felt the same way they did about the program. Some of the comments included; “*not many people that I've really been with, or run in the circle that I do, never really saw the upside of it to start with*”, “*Why are we designated to put up with it? I don't know*”, “*I would say right down today there's probably better places to put them. Now what that is, I don't know*”, and “*They’re like me, they don’t really see the benefit of it*”.

In our quantitative survey, when asked to state their level of support for conserving red wolves, the highest percentage of the probability (53%) and convenience (50%) samples supported while 17 – 21% were neutral and 6 – 14% opposed. (Fig 6). In our probability sample, the only significance was between non-hunters who were more supportive than hunters, however every group tested within the convenience sample were significantly different (Table 4).

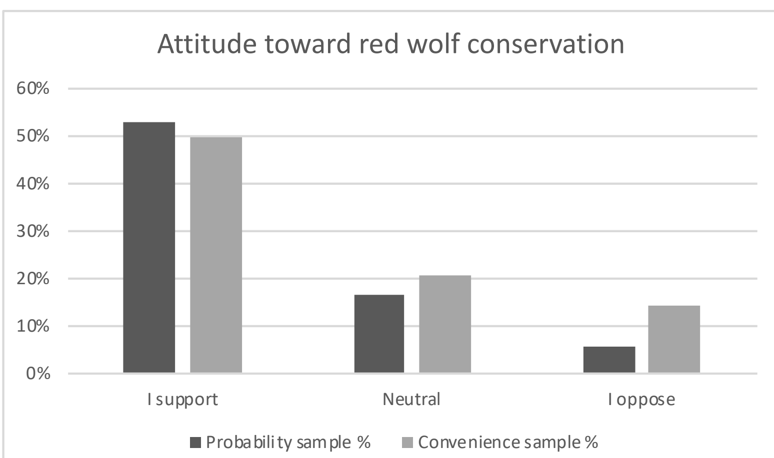

Fig 6. Support for red wolf conservation by sample

3.2.3 Attitude toward red wolf policy proposal

Most interviewees were unaware of the new proposed policy (announced only a couple months before our interviews) and most were also unaware of current regulations surrounding red wolf management. One interviewee believed the red wolves had already been removed and were no longer being managed in NC. When we explained the new proposed policy, one participant stated, “*If they've decided that, they already own the land, this is what they're going* *to do, and we're going to try to keep the red wolves on our property and take care of them for a while. So be it. That's probably a good place then.*" Another said, "*I think it's exactly what they need to do*". One participant was aware of the new proposed policy and expressed frustration in how information was or was not provided to residents. "*One that really is really irritating me about the way this new proposed rule is being publicized. And this is not Fish and Wildlife that's doing this. This is the proponent groups that are pushing it. They're trying to paint this as… we're getting ready to have a big wolf killing down here".* He went on to explain his frustration with how both pro-wolf and anti-wolf groups were misrepresenting the situation.

In our quantitative survey, when asked about their attitude toward the proposed policy, the probability sample reported mostly neutral attitudes (23%), followed by dislike (19%) and like (15%) (Fig 7). The convenience sample reported more negative attitudes of dislike (25%), followed by like (21%) and neutral (13%). Within the probability sample, only farmers chose a significantly more positive attitude toward policy than non-farmers. In the convenience sample hunters were significantly more positive than non-hunters, farmers were more positive than non-farmers, and males were more positive than females (Table 4). A more favorable response to this policy would show an unfavorable attitude toward red wolves since this policy allows for more freedom to kill red wolves.

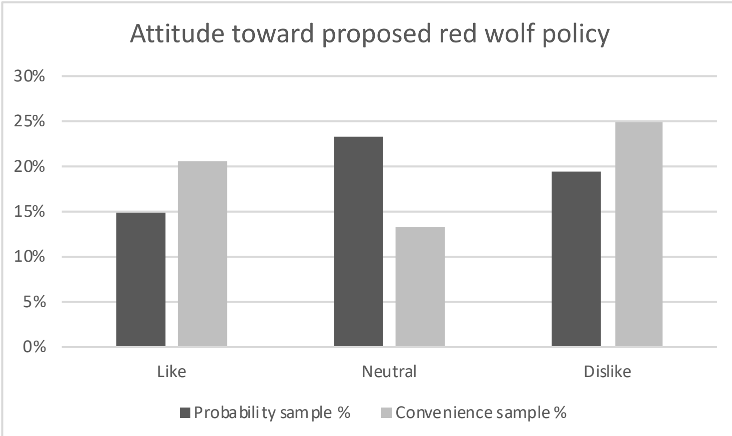

Fig 7. Attitude toward the proposed red wolf policy by sample

3.2.4 Trust for USFWS (management agency)

Trust in USFWS varied among interviewees. Their responses ranged from trust to acceptance to mistrust. One interviewee explained how the USFWS was always "*dumping animals on the refuge*" and said "*They're deceitful. They work underhanded*". He felt they only cared about the wildlife and nothing else. Other statements included, "*You know Fish and Wildlife, I know that the Federal Government owns so much land and has such a presence here, I kind of expect them to be here, I guess*". Another interviewee stated, "*They're here for a reason and I ain't got no problems with them*". One attitude that was consistent across all interviews was appreciation for individual representatives of the USFWS who were well-liked even among those who disliked the red wolf program. Several stated they were only willing to work with the USFWS and would not kill a red wolf because of their relationship with those individuals.

A higher percentage of both the probability sample (37%) and the convenience sample (46%) chose trust for the USFWS (Fig 8) more than neutral or mistrust. The only significant differences in trust for the USFWS in the probability sample was between farmers who responded they trusted the USFWS more than non-farmers and for the convenience sample between females who chose trust more than males (Table 4).

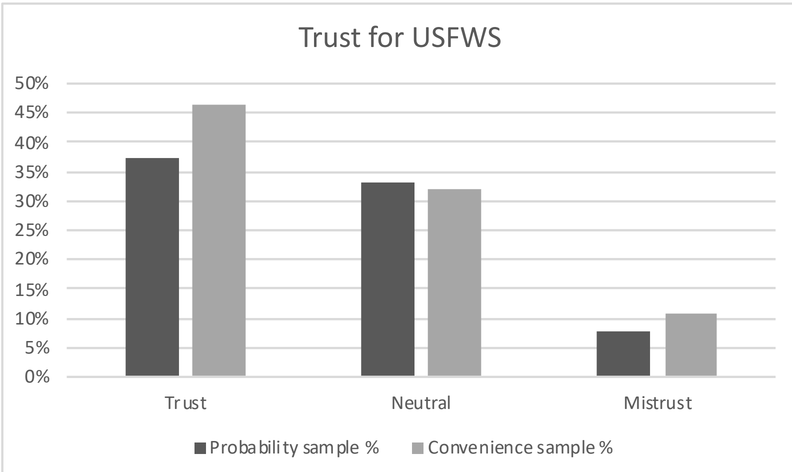

Fig 8. Trust for the USFWS by sample

3.2.5 Acceptance

Out of all four attitude variables, both samples reported a high level of support for red wolf conservation (Mdn = 2 (1-2)), while the probability sample are more positive in their attitude toward red wolves (Mdn 2 (1-2) and 1 (1-2), z = -2.39, P = 0.017) and lower in their trust for the USFWS than the convenience sample (Mdn = 1 (1-2) and 2 (1-2), z = 0.427, P = 0.670). Both reported a low median attitude (Mdn =1 (0-2)) for the new proposed policy (Fig 9).

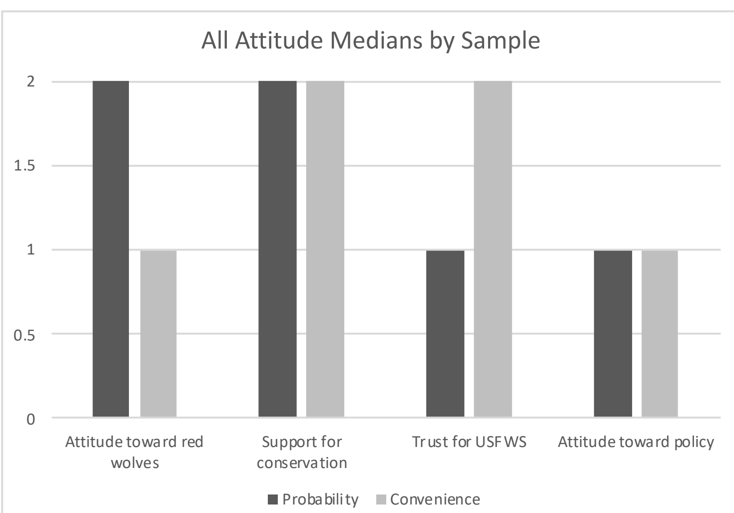

Fig 9. Median attitudes for all four variables used in acceptance; attitude toward red wolves, support for conservation, trust for USFWS, and attitude toward policy. Attitudes measured from 0-2

We combined the four attitude variables into one acceptance variable (Fig 3) to represent overall acceptance for the red wolf program. There were no significant differences between the two samples, but within the convenience sample, hunters have a lower median acceptance score than nonhunters (Mdn = 2(0-4) and 4(3-5), z = 3.68, P <0.001) and males have a lower median acceptance score than females (Mdn = 3(1-4) and 5(3-6), z = -3.39, P <0.001) (Table 5). With a midpoint of 2.0, 63% of the probability sample and 65% of the convenience sample have median acceptance scores above 2.0 showing a high overall acceptance of the red wolf program (Fig 10).

Table 5. The acceptance metric was calculated to include attitude toward red wolves, support for conservation, attitude toward red wolf policy proposal and trust for the USFWS.
Overall metric ranged from -2 to 6 with higher numbers indicating greater acceptance, and a midpoint of 2.

	Probability sample			Convenience sample		
Group	n	%	Median	n	%	Median
Hunters	79	27.4%	3	49	43.8%	2
Non-hunters	209	72.6%	4	63	56.3%	4
Farmers	94	32.6%	4	37	33.0%	3
Non-farmers	194	67.4%	3	75	67.0%	4
Residents	115	39.9%	3	71	63.4%	3
Non-residents	173	60.1%	4	41	36.6%	4
Males	78	27.1%	4	67	59.8%	3
Females	203	70.5%	4	41	36.6%	5
Overall Acceptance	288		4	112		3.5

Shaded rows are significant at P <0.05

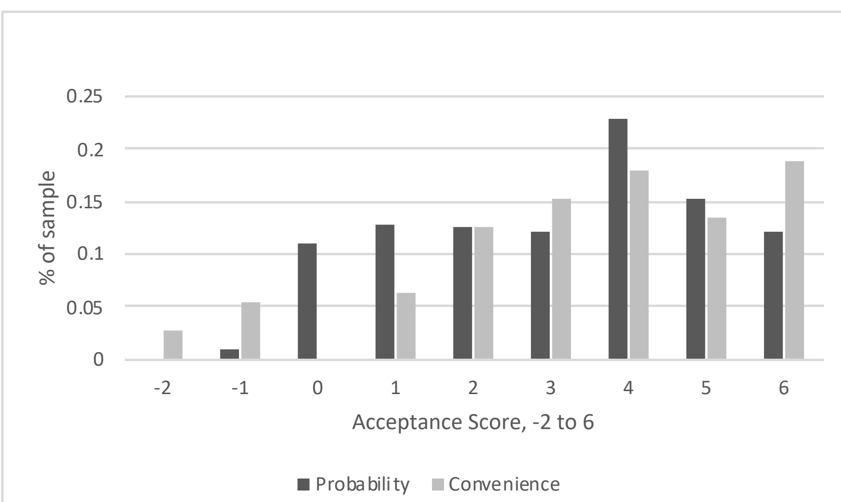

Fig 10. Histogram showing acceptance for the red wolf program by sample. Higher values represent higher level of acceptance with a midpoint of 2.

3.3 Experience

We had two direct experience questions in our study; “seen a red wolf in the wild”, and “heard a red wolf in the wild”. In the probability sample, the 41% who reported having direct experience held a significantly more positive median attitude of 6(4-7) while those without experience had a median attitude of 5(4-6) ($z = -3.02$, $P = 0.003$). Forty-eight percent of the convenience sample reported having direct experience, and their median attitude was 4(3-6) while those without direct experience had a higher median attitude (though not significant) of 5(4-6) ($z = 1.45$, $P = 0.15$).

Respondents in the probability sample with any type of experience were significantly more positive than those who did not ($Mdn \geq 6$, $z \leq -2.1$, $p < 0.036$ for every type of experience) except “attended a red wolf information meeting”. Those who chose “no experience” were also less positive than those who didn’t choose this response (Mdn = 4(4-6) and 6(4-7), $z = 4.51$, $P = 0.001$). The portion of the convenience sample who reported the following types of experiences responded with significantly more positive attitudes toward red wolves than those who did not have those same experiences: had attended a red wolf meeting (Mdn = 6(6-7) and 4(4-6), $z = -2.41$, $P = 0.016$), seen an educational display (Mdn = 6(4-7) and 4(4-6), $z = -2.11$, $P = 0.035$) or visited a red wolf howling event at ARNWR (Mdn = 6(6-7) and 4(4-6), $z = -2.57$, $P = 0.01$).

3.4 Behavioral Inclination

All of the interview participants said they would not want to shoot a red wolf but there were some instances in which they would. When asked directly if they would kill one, one participant stated, “*No. But now if I saw one that I thought was approaching me, looked kind of ... I might would then, or if it was out there around my grandkids or something like that, and he was approaching them. I probably wouldn't ask questions twice. Even if he had a collar on* *and a guy was standing there with handcuffs on, I'd probably still do it".* Another participant who had expressed not wanting red wolves in the area stated in regard to killing one, "*I don't have a desire to, and I really don't*".

One participant identified as a poacher and described killing a red wolf that came onto his property. Before shooting it, he believed it was a wild dog like others he regularly had problems with on his property. When asked if he would do it again, he said, "*If I see one with a collar on I might not. If I see one where I'm deer hunting or around my cows, it got to go. Around my house, I'd shoot it if I get the chance*". However, upon further discussion, this same participant also explained that now since he knows what to do, he would call a contact with the USFWS if he saw one. I asked what would stop him from shooting a red wolf and he said, "*The law. The law. Yeah, the law would make me stop. I don't want to go to jail*". He remembers seeing signs up. "*I had heard that there was signs on there that 100 thousand dollars for disturbing a red wolf. For disturbing. Much less killing*".

Interview participants believed there were others that would or have killed a red wolf. While one participant had not seen a red wolf himself, he shared stories from others describing exactly how to kill a red wolf and avoid detection.

For behavioral inclination index, participants' scores ranged from 0 to 9 with higher numbers representing a higher number of situations in which they would make a lethal choice. The probability sample had a significantly lower index than the convenience sample meaning they would choose to kill a red wolf in fewer situations (Table 6). Hunters showed a significantly higher inclination to poach than nonhunters in both the probability sample and the convenience sample. Males had a significantly higher score than females only in the convenience sample.

Table 6. Behavioral inclination index by sample and group.

Scores are index summed from questions 11 and 14 with higher scores reflecting a higher number of situations in which a respondent would choose to kill a red wolf.

		Probability Sample, n = 288					Convenience Sample, n = 112				
	Group	n	%	Median	IQR	z, P	n	%	Median	IQR	z, P
Behavioral Inclination Index	Sample	288	100.0%	0.0	0-1		112	100.0%	1.0	0-1	4.44, <0.001
	Hunters	79	27.4%	1.0	0-1	-3.09, 0.002	49	43.8%	1.0	1-2	-3.69, <.001
	Non-hunters	209	72.6%	0.0	0-1		63	56.3%	0.0	0-1	
	Farmers	94	32.6%	1.0	0-1	-3.24, 0.001	37	33.0%	1.0	0-1	-0.89, 0.38
	Non-farmers	194	67.4%	0.0	0-1		75	67.0%	1.0	0-1	
	Residents	115	39.9%	0.0	0-1	-1.15, 0.25	71	63.4%	1.0	0-1	0.57, 0.57
	Non-residents	173	60.1%	0.0	0-1		41	36.6%	1.0	0-1	
	Males	78	27.1%	0.0	0-1	0.46, 0.65	67	59.8%	1.0	0-2	3.65, <.001
	Females	203	70.5%	0.0	0-1		41	36.6%	0.0	0-1	

*Shaded areas are significant at p = <0.05 when comparing groups using Mann-Whitney median test.
*% is out of respondents identifying in that group.

From our surveys there were significant differences in the two samples for behavior choices. When asked under what situations they would try and kill a red wolf, the nonlethal choices of “I would not kill a red wolf” (65% v 41%, $\chi^2 = 18.30$, df = 1, P <0.001), and “I would try to protect it” (15% v 6%, $\chi^2 = 5.91$, df = 1, P = 0.015) were significantly higher for the probability sample. Each of the following lethal behaviors were significantly higher in the convenience sample: “the wolf did not run away from me when I was on foot” (19% v 7%, $\chi^2 = 12.22$, df = 1, P <0.001), “the wolf came too close to my home” (18% v 7%, $\chi^2 = 9.79$, df = 1, P = 0.002), and “the wolf approached my pet or farm animals” (47% v 17%, $\chi^2 = 37.86$, df = 1, P <0.001).

We found that choosing to not kill a red wolf was not mutually exclusive from lethal choices since 12 of 232 people (186 probability, 46 convenience) who chose “I would not kill a red wolf” chose at least one situation in which they would. Within all survey responses, more respondents chose "I would not kill a red wolf" than any other behavior at 65% for probability and 41% for the convenience sample. In question 14 there were other behaviors they could choose when seeing a red wolf on their property. Fifty-one respondents (7 convenience, 44 probability) reported they would protect a red wolf on their property, and only 11 (6 convenience, 4 probability) chose “I would try to kill it” but all of those respondents also chose

"I would not kill a red wolf" in Q11. Nonlethal behaviors in Q14 such as watching and calling authorities were also associated with lethal behaviors in Q11.

3.5 Correlations between attitude and behavioral inclination

Attitude (using the Likert scale of 0-7) and behavioral inclination index (0-9) showed a significantly negative relationship in both the probability sample ($r_s = -0.25$, P <0.001) and convenience sample ($r_s = -0.54$, P <0.001) using a Spearman rank correlation coefficient, meaning that respondents with positive attitudes toward red wolves had lower inclinations to poach them. Looking in more detail at each behavior, the Mann-Whitney test shows a significant relationship between specific attitudes and behaviors (P = < 0.05) in 8 out of 15 situations for the probability sample and 9 out of 15 for the convenience sample (Table 7).

Table 7. Relationship between Attitude (Q8) and Behavioral Inclination (Q11 and Q14) by sample.

Q11 It is currently against the law for a private citizen to kill a red wolf except in defense of life (human, livestock, or pets). Are there any other situations you might try to kill a red wolf anyway (choose all that apply)? Q14 What would you do if you saw a red wolf on your property (choose all that apply)? Q8 How would you describe your general attitude toward red wolves?

Probability sample	Attitude										
Behavior	Like		Neutral		Dislike		I don't know		Median	z	p
Q11	n	%	n	%	n	%	n	%			
Any wolf I encounter on my own	6	42.9%	5	35.7%	2	14.3%	1	7.1%	4 v 6	0.89	0.370
The wolf did not run away from me when I was on foot	6	30.0%	10	50.0%	4	20.0%	0	0.0%	4 v 6	2.83	0.005
The wolf did not run away from my vehicle	3	42.9%	3	42.9%	1	14.3%	0	0.0%	4 v 6	0.74	0.460
The wolf was on my property	4	40.0%	8	40.0%	4	20.0%	0	0.0%	4 v 6	2.48	0.013
The wolf came too close to my home	11	52.4%	4	19.0%	6	28.6%	0	0.0%	5 v 6	2.09	0.040
The wolf approached my pet or farm animals	27	54.0%	16	32.0%	7	14.0%	0	0.0%	5 v 6	1.60	0.110
I would not kill a red wolf	113	60.8%	44	23.7%	9	4.8%	20	10.8%	6 v 4	3.94	<0.001
I would support someone else killing a red wolf	3	33.3%	4	44.4%	1	11.1%	1	11.1%	4 v 6	1.55	0.120
Q14											
I would try to protect it	33	75.0%	7	15.9%	3	6.8%	1	2.3%	6 v 5	-2.96	0.003
I would watch it	92	67.2%	34	24.8%	6	4.4%	5	3.6%	6 v 4	-3.71	<0.001
I don't know	14	40.0%	10	28.6%	2	5.7%	9	25.7%	5 v 6	1.19	0.240
I would call the authorities	27	50.0%	13	24.1%	8	14.8%	6	11.1%	5 v 6	2.10	0.036
I would try to kill it	3	75.0%	0	0.0%	1	25.0%	0	0.0%	6.5 v 5.5	-0.68	0.490
I would try to scare it away	21	42.0%	19	38.0%	8	16.0%	2	4.0%	4 v 6	2.50	0.013
I would ignore it	20	60.6%	7	21.2%	2	6.1%	4	12.1%	6 v 6	-0.36	0.720

Convenience sample	Attitude										
Behavior	Like		Neutral		Dislike		I don't know		Median	z	p
Q11	n	%	n	%	n	%	n	%			
Any wolf I encounter on my own	0	0.0%	1	50.0%	1	50.0%	0	0.0%	2.5 v 4	1.53	0.130

The wolf did not run away from me when I was on foot	4	19.0%	8	38.1%	9	42.9%	0	0.0%	4 v 5	3.57	<0.001
The wolf did not run away from my vehicle	0	0.0%	0	0.0%	2	100.0%	0	0.0%	1 v 4	2.32	0.020
The wolf was on my property	1	11.1%	2	22.2%	6	66.7%	0	0.0%	2 v 5	3.25	0.001
The wolf came too close to my home	3	15.0%	4	20.0%	13	65.0%	0	0.0%	3 v 5	4.67	<0.001
The wolf approached my pet or farm animals	16	30.2%	19	35.8%	17	32.1%	1	1.9%	4 v 6	3.87	<0.001
I would not kill a red wolf	33	71.7%	10	21.7%	1	2.2%	2	4.3%	6 v 4	5.01	<0.001
I would support someone else killing a red wolf	0	0.0%	1	20.0%	4	80.0%	0	0.0%	1 v 5	3.10	0.002
Q14											
I would try to protect it	7	100.0%	0	0.0%	0	0.0%	0	0.0%	7 v 4	-3.10	0.002
I would watch it	32	49.2%	26	40.0%	6	9.2%	1	1.5%	4.5 v 4	-1.71	0.090
I don't know	2	20.0%	7	70.0%	1	10.0%	0	0.0%	4 v 5	1.37	0.170
I would call the authorities	7	43.8%	6	37.5%	3	18.8%	1	6.3%	4 v 4	0.04	0.960
I would try to kill it	0	0.0%	2	33.3%	4	66.7%	0	0.0%	2 v 5	2.96	0.003
I would try to scare it away	17	51.5%	7	21.2%	9	27.3%	0	0.0%	5 v 4	-0.47	0.640
I would ignore it	5	50.0%	1	10.0%	3	30.0%	1	10.0%	5 v 4	0.48	0.630

% is out of all respondents who checked that behavior
Mann-Whitney z is measuring the significance of association between attitude and each behavior
Median is the median attitude value for those who selected that response v those who did not.

4. Discussion

Our goal was to measure attitudes toward red wolves and red wolf management along with respondents' behavioral inclinations for those who live in and around the red wolf reintroduction area. Anthropogenic mortality is the largest threat to the survival of the only wild population of this species, and by understanding how people think about red wolves and their conservation, decisions can be made about how and where to concentrate outreach efforts and interventions. With the last published estimate of 44 individuals (Weller, 2018) and a known population of 19, estimated 23-30 red wolves remaining as of December 2018 (USFWS personal communication) urgent action is needed to ensure their survival. From our conversations with those most closely tied to red wolf recovery, it is believed that the reason red wolves are illegally killed is because a majority of landowners have a negative attitude toward them and do not want them there. The USFWS explicitly states that the current regulations are not effective in fostering coexistence between people and red wolves (Kurth, 2018). However, in our study we found a majority of respondents had positive attitudes toward both red wolves and their conservation and those who dislike them are in a small minority. There is also a large percent who don't know or are neutral about the program. Our interviews and survey responses reflect a distinction between attitude toward red wolves and attitudes toward the program which is important and leaves an opening for education and cooperation.

4.1 Sample Characteristics

Our two samples were demographically different, with the probability sample predominately younger, more female and more non-residents while the convenience sample was older, male dominated and more residents of the RWRA. Both samples were also different from the census and so is not representative of the area. As with past wolf surveys in Wisconsin, cited in the Methods, salience of surveys about wolves to older respondents might explain the older convenience sample and Qualtrics panels tend to be younger with 62% of the nationwide panel under the age of 34 (Qualtrics communication). As expected, this resulted in differences between our two samples in measures of attitude with the probability sample being more positive toward red wolves and their conservation and a higher level of acceptance for the program. The probability sample also had significantly higher responses for behavioral inclination choices of "I would not kill a red wolf" and "I would try to protect it" than the convenience sample. This aligns with studies that show females to be more involved in animal advocacy than males (Herzog Jr et al., 1991; Kellert and Berry, 1987; Peek et al., 1996), stronger advocacy in the younger generation (Bryan, 2008; Firkins, 2017), and more positive attitudes in those living outside wolf areas (Karlsson and Sjöström, 2007). However, the convenience sample had higher percentages of individuals identifying as wildlife, conservation, animal welfare and environmental advocates than the probability sample suggesting the relationship between gender and advocacy may be more complicated.

Attitudes toward animal welfare, its state as regards its attempts to cope with its environment (Broom, 1988), have changed over the years and gender has been shown to be one of the most influential variables (Coleman, 2008). For our study, males and females in both samples did not differ in their identification for animal welfare or environmental advocate as gender studies have shown, however there was a significantly higher percentage of males in the convenience sample that were wildlife and conservation advocates. The probability sample did not differ by gender for any category and so differences in attitude and behavioral inclination between the two samples may be more representative of shared values between males and females who participate in pre-recruited panels. What it means to be a wildlife advocate, for example, may very well have a different meaning depending on gender and age and would be a good topic for a future study.

4.2 Attitude, Experience, and Behavior

While other wolf studies have shown declining tolerance for wolves over time (Treves, et al., 2013), our study showed consistently positive attitudes toward wolves and their conservation when compared to earlier data collection. There were two studies conducted in 1995 that asked about support for red wolf recovery. One of those was a thesis conducted by NC State University which focused solely on the RWRA (Quintal, 1995) and one which covered eight different states (Rosen, 1997), both of which were also demographically non-representative of the census population. Quintal (1995) reported that 51.7% of participants supported red wolf recovery, whereas Rosen (1995) reported strong support for red wolf recovery in NENC with 75% of respondents favoring recovery.

Compared to Quintal (1995), our study 23 years later shows positive attitudes toward wolves have increased by 19.2%. Negative attitudes decreased by 4% and those who are neutral or don't know have also decreased by 19.2%. Location differences in attitude are generally the same as 1995 scores where Dare county, containing Alligator River National Wildlife Refuge where red wolves were first introduced and the Outer Banks area, is the most positive. Those attitudes may reflect many elements including location of USFWS offices, high levels of education and red wolf meetings, low human population around the refuge, low human-wolf interaction, or others. Study participants in Hyde county, located just south of the refuge were the most negative among the 5 RWRA counties. There are large tracts of private land in this county where red wolves are most able geographically to disperse when leaving the refuge. While this county has the most negative attitudes toward red wolves in our study, it also has the lowest human population and understandably the lowest response rate (Fig 5). A larger representative sample may show a different result. With the high possibility of red wolf dispersal, large areas of private land, low human population, and negative attitudes, Hyde county would be a good target area for outreach efforts to landowners.

Every type of experience with red wolves was associated with more positive attitudes toward red wolves. We cannot determine if certain experiences led to a more positive attitude or if those with more positive attitudes sought out those experiences. Also, considering the direct experience reported outside the range of red wolves, the elusive nature of the species, and the presence of coyotes, we expect at least some respondents to have mistaken their identity. What we do know is that interviewees who had discussions and worked with USFWS field personnel changed their behavior based on those experiences. Those with indirect experience and loosely held attitudes are usually more subject to change (Ericsson and Heberlein, 2003). With 57% of our respondents reporting only indirect experience and 37% without an opinion about red wolves, there is a high possibility for change in NC. Interviewees and survey participants (who added additional comments) expressed the desire for greater involvement in the process and better communication with management agencies. When asked about outreach efforts concerning red wolves in the area, interviewees could not remember any efforts by the USFWS that took place outside of Dare County and Roanoke Island. While several of them worked with individual employees over the years, those meetings only occurred after the wolves were already on their property.

Daley et al (2004) showed regionally unique wildlife values within the state of NC where landowners found wildlife to be important including knowing they lived on their property, being able to watch wildlife, and protecting wildlife. Here property rights are seen as an important principle related to wildlife and some landowners are wary of state-assisted programs. However, this attitude study showed models of successful wildlife management programs in certain parts of the state with an emphasis on personal relationships with agency personnel. Those authors concluded any management considerations would need to include local and regional attitudes (Daley et al., 2004). Most of our participants shared frustration for the continued lack of communication between managers and the residents who are living with red wolves. Even though trust for the USFWS scored high in our study, responses such as this show there is a lot of room for improving relationships with private landowners. How attitudes change in the future may depend on those decisions made by agency personnel and other stakeholders.

Measures of acceptance are useful as a general indicator of the tolerance for a species in a particular location and context (Zajac et al., 2012). Zajac et al. (2012) found that increased trust in the agency led to increased acceptance for black bear populations since trust increases perceptions of benefits and lowers risk perception (Zajac et al., 2012). This was clearly demonstrated in our interviews in which every person related a positive relationship to USFWS personnel with their acceptance of red wolf conservation even with their questions and/or dissatisfaction with how reintroduction took place. Decker & Purdy (1988) describe the concept of acceptance as wildlife acceptance capacity (WAC) in which different groups can have a different acceptance value, useful in understanding how wildlife management decisions affect public opinion. It is acceptance for a defined area at a given point in time. Our acceptance variable, reflecting the current state of red wolf management, shows a high level of acceptance across all groups of our survey respondents. However, since the most recent policy proposal was negatively correlated with their survival, it decreased acceptance scores. Understanding acceptance is important, and requires managers to be responsive to individual group needs, if species conservation is to be successful (Decker and Purdy, 1988).

The new USFWS red wolf policy proposal would limit protections of red wolves to federal lands on the Albemarle Peninsula, allowing take of red wolves on private land, whereas the current policy does not limit protection geographically. This gave us an opportunity to ask residents their attitudes toward that policy and we found that a high number (42% “I don’t know” and 21% “neutral”) of respondents reported not knowing how they felt. Comments from both interviewees and survey respondents showed they were either not aware of the policy proposal or didn’t understand it. This was also reflected in how many policy questions were asked by participants in their responses and the request for more information during the study. Among those who did have an opinion, we found limited support reported for this policy that would allow the killing of red wolves on private property. Research would be needed to show if a more favorable policy toward red wolf survival would increase acceptance.

4.3 Poaching

Fifty-five percent of respondents responded that they would not kill a red wolf in any situation. While promising, that means that there is still 45% that reported lethal behavioral inclination toward a red wolf, the majority being if the wolf approached their pet or farm animal, similar to other wolf poaching research (Browne-Nuñez et al., 2015). A few of our respondents who said they wouldn't kill a red wolf still selected that they would kill in a few situations, leading us to believe they may have misread the survey question. The designation of nonessential experimental allows the USFWS to remove wolves for any reason at the request of landowners, which should reduce the incidents of illegal killing in those cases but only if landowners are aware of policy and have the resources for communication. With the number of "I don't know" responses regarding policy, there is room for improvement.

It only takes one person to poach a red wolf and with such a small population, the loss of just one breeder can have devastating effects on the wild population. In our study, male hunters had the highest mean behavioral inclination to poach and the lowest level of acceptance of any stakeholder group, but even these values showed a very low inclination of 0-1 and a level of acceptance above the midpoint. Hunters also have opportunity during hunting season where they will likely be carrying a firearm in areas with red wolf prey, and therefore red wolves. However, since more than 79% of our respondents who are hunters, also identify as wildlife and conservation advocates, our respondents may reflect an attitude more conducive to red wolf management.

4.4 Salience

The red wolf recovery program was implemented over 30 years ago. With a high profile and controversial species along with a small human population, we would expect salience to be high for residents of the five-county area. However neutral attitudes toward red wolves ranged from 40% in Tyrell county to 15% in Hyde county. We expected red wolf conservation to have higher salience for our convenience sample and lower for our probability sample, which was supported by our results. "I don't know" responses were higher in the probability sample for attitude toward red wolves (probability = 8.3% and convenience = 2.7%), support for red wolf conservation (25% and 15%), and trust for the USFWS (22% and 10.7%). Our results show a lower level of salience overall than in other wolf studies (Browne-Nuñez et al., 2015)(Karlsson and Sjöström, 2007). We are unable to determine if this represents apathy toward red wolves in this region or lack of knowledge and recommend more research be conducted to determine those reasons. At the very least this presents a clear opportunity for education.

4.5 Study limitations and bias

Online surveys such as ours give the ability to reach people regardless of distance, do not require face-to-face meeting, allow for confidentiality, and are cost-effective. The disadvantages include a traditionally lower response rate, problems with excessive survey length, lack of interest, and lack of accessibility for some portions of the general population such as the less educated and those without internet (De Leeuw, 2012; Dillman et al., 2010), resulting in a sample that may not be representative of the underlying population. Asking fewer questions to increase response rates came with the trade-off of not being able to ask everything we would have liked to. Therefore, there may be other factors involved in attitude and behavioral inclination that we didn't assess, such as religious, economic and more value-laden questions. Specific questions we would also ask in another survey include; motivations to conserve red wolves, interventions they believe would prevent poaching, how they would like to be involved in reintroduction, and place-based values. Since our study was conducted in a small geographic area, we were not able to achieve a representative sample, even with the addition of a paid pre-recruited panel and so results should be interpreted within this context. However, the sample was still useful as participants were diverse, spread throughout the entire geographic area we sampled, included more than the number of participants recommended, and included an over-representation of target groups such as hunters.

Finally, we were contacting participants for our study when Hurricane Florence made landfall in September 2018, which limited our ability to reach landowners for interviews. Since the area was evacuated, we waited an additional month to send out our internet survey, however due to the weather and damage to the Albemarle Peninsula, it may have lowered our response rate as residents were focused on more urgent matters.

4.6 Recommendations beyond NC and beyond wolves

Fragmented protected areas such as those found in the North Carolina red wolf reintroduction area, are unable to contain large carnivores who will disperse into surrounding land, seeking territory as the population grows. As red wolves continue to move outside of protected boundaries and onto private lands, poaching may continue to be a problem impacting wolf populations and increasing social conflict in the area. Research that is interdisciplinary and involves reconciliation ecology will be needed to conserve species within these human-dominated landscapes.

Mixed methods research also proved to be beneficial at all stages of our study. Our in-depth interviews revealed the amount of complexity involved in both attitudes and behavior toward a predator such as red wolves. It also allowed us to ask follow-up questions giving us deeper insight into the evolution of the red wolf program and how attitudes have developed over the course of reintroduction. While we were not able to do the same with our online survey, the anonymity allowed respondents to indicate killing inclination without fear of penalty, which has been noted by other studies on behavioral inclinations (Browne-Nuñez et al., 2015).

Many avenues for future research involving large carnivores have been offered throughout literature and can be applied to red wolf recovery. Large carnivore conservation programs that improve the social and financial welfare of the impacted communities are needed. These should include strategies that resolve problems while safeguarding both humans and the species/environment (Jhamvar-Shingote and Schuett, 2013). Interviews revealed one of those problems to be economic priorities in the region, which have partly been addressed through jobs created with the red wolf recovery program. Others have not been such as the tax burden placed on residents with federal land ownership changes. While we cannot speak to the details of these issues, perceived problems such as these are real to those who experience them and is an opportunity for the management agency to increase acceptance.

These studies should also incorporate longitudinal data collection over time to determine how attitudes change in response to conflict. Micro (individual) to macro (culture) models can explain the behavior of individuals and then provide structure for research across cross-cultural contexts (Manfredo and Dayer, 2004). With motivations supported by societal conflicts, a better job of including stakeholders in the process and management is needed to bring those groups closer together and minimize polarization. Rather than focusing on more positive or more negative attitude development, research and management should incorporate resolution to landowner concerns to create common ground. Proximate mechanisms leading to wolf poaching are also under-studied and we know little about encounter rates, the inclination of humans to react lethally and the probabilities those reactions will succeed (Treves, et al., 2017b)(Treves et al., 2017b)(Treves et al., 2017b). Treves (2017b) also suggests research that interviews confirmed poachers to test causal mechanisms, opportunistic encounters and triggering events.

While we were able to interview one confirmed poacher in this study, a single event cannot give us the depth of information we need to understand the larger population.

At this point the outlook of the red wolf recovery program is uncertain. A decision is expected soon from the USFWS regarding the future of the North Carolina population and speculation is they may limit red wolves to only ARNWR (152,000 acres) and the Dare County Bombing Range (46,000 acres) that will only hold a small group (one or two packs consisting of fewer than 15 animals). It would change the role of the population to providing a source of red wolves, raised in natural conditions, for future reintroduction sites (Kurth, 2018). The latest USFWS red wolf 5-year review determined the non-essential experimental population (NEP) status was not effective at protecting the red wolf from illegal take and the population would need substantial intervention to survive. With the new policy, the entire NEP area of 1.7 million acres would be reduced by almost 90% to only 198,000 acres. Whether recovery in North Carolina is a success or failure, we need to understand how management can be improved in the future based on the experience of those from the past and present recovery areas. Should red wolves be reintroduced into new sites in the U.S., as goals for the red wolf recovery plan mandate, managers need to understand who is poaching, why they poach and why the problem continues to persist in order to make good decisions for future recovery of the species. Our study revealed that even with high acceptance and positive attitudes, anthropogenic mortality including poaching is still the number one threat to red wolf survival. While studying attitudes as we have here is a good start and gives us insight into motivation, we also need to understand the conditions of opportunity such as the ability to kill a red wolf and the circumstances surrounding encounters.

5. Conclusion

Our study highlights the importance of relationship between agency personnel and landowners, not only in response to wolf-human interactions but throughout the entire process of recovery including decision-making. Through our interviews and surveys, a common theme expressed by landowners was the absence of information regarding red wolves and their conservation since the inception of the program 32 years ago. Respondents already express a pro-conservation attitude along with their positive views of red wolves, but there was still a large segment of our study that does not feel strongly about wolves. This provides potential to improve attitudes through outreach, but it also means those individuals could become more negative if media and communication is more negative. Most critical are proven interventions that mitigate poaching while building human-wolf coexistence. Currently we don't know what the future for red wolves in NE NC will be as we wait for final policy decision from the USFWS. If policy allows them to remain protected throughout the current NEP area, then management will need to include continued support for and communication with landowners as well as continued research into the underlying motivations for poaching to reduce anthropogenic mortality.

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Chapter 4: Spatial analysis of poaching risk for red wolves (*Canis rufus*) in northeastern North Carolina: social and ecological implications for survival

Suzanne Agan

Antioch University New England

Abstract

Currently, anthropogenic mortality is the leading cause of death for all wild red wolves in the endangered NENC population with poaching accounting for the majority of those deaths. Being able to predict conflict locations and prevent poaching can reduce cost for conservation and landowners and spatially explicit analysis of ecological and social factors influencing survival has been used successfully for conservation purposes for a number of other species. Traditionally, wildlife habitat suitability models have not used social attitudes as part of their spatial analysis, which has been a major limitation in determining suitable habitat. Wolves, however, move into areas occupied by humans, including areas owned by landowners whose understanding of nature does not include large carnivores. While ecological conditions may be favorable for wolves, human acceptance may be low and illegal killing behaviors may be the result. Our goal was to conduct a spatial analysis that combines ecological and social risk factors to identify areas where wolves are most vulnerable to poaching in NENC in order to inform future management efforts. We identified environmental variables on the landscape that are associated with red wolf mortality and combined them with results of an attitude survey concerning red wolves and their conservation to test how they inform overall risk spatially. Finally, we looked for areas where red wolves are most likely and least likely to be poached to create a predictive layer of poaching.

Our predictive model of poaching performed well, with the highest risk values west of management areas, close to paved roads, in agricultural land cover, areas of high deer harvest, and where human population was higher. Risk was also highest in areas where behavioral inclination to kill a red wolf was higher. The results suggest that poaching risk can be identified

on the landscape, social variables should be included in analysis, and could be used by wildlife managers to tailor conservation interventions appropriately.

Key words

Red wolves, poaching risk, carnivore conservation, spatial analysis, human-wolf conflict, management area

Introduction

Even with legal protections, anthropogenic mortality is causing population decline in mammalian carnivores around the world (Treves and Bruskotter, 2014). Wolves are killed by humans who dislike wolves (or their management), causing high rates of anthropogenic mortality and negatively influencing population growth (Bruskotter et al., 2014). While many studies show wolves have high levels of persecution (Browne-Nuñez et al., 2015; Treves et al., 2017a, 2017b), the persistence of some carnivore populations in areas of high human density demonstrates that human-carnivore coexistence is possible under the right conditions (Carter et al., 2012; Llaneza et al., 2012). For example, Carter et al. (2012) found that tigers and humans co-existed even at small spatial scales, likely because tigers adjusted their activity due to human presence. In North America, Linnel et al. (2001), found that carnivore populations increased after favorable policy was introduced, despite increases in human population density. With more in-depth spatial knowledge, conservation managers can focus resources where poaching is high such as with red wolves in Northeastern North Carolina (NENC).

Currently, anthropogenic mortality is the leading cause of death for all wild red wolves in the endangered NENC population (Hinton et al., 2016b). In the first 25 years of reintroduction, 72% of known mortalities were caused by humans, and in many cases were avoidable. These included suspected illegal killing, vehicle strikes, and private trapping (Bartel and Rabon, 2013). Gunshot mortalities alone increased by 375% in the years 2004 – 2012 compared to the 5 previous years (Bartel and Rabon, 2013) and increased 7.2 times during deer hunting season when compared to the rest of year. The Red Wolf Species Status Assessment (SSA), US Fish and Wildlife Service (USFWS), Rivenbark et al. (2018), and Hinton et al. (2016b) all report that gunshots were the most frequent cause of death for wild red wolves. A higher percentage of wolves that go missing, becoming fate unknowns (FU), are unrecovered during this same time as opposed to outside hunting season (Hinton et al., 2015).

The five counties in the Red Wolf Recovery Area (RWRA) still have some of the lowest human densities in the state of NC, however the human population is growing in these areas and the number of hunting licenses has continued to increase each year. Between 2011 and 2018, licenses increased 27% in Dare county, 20% in Beaufort, 11% in Hyde, 11% in Tyrell, and 8% in Washington (NC Wildlife Resources Commission, 2019). Since gunshot mortalities of red wolves are higher during hunting season, additional hunters on the landscape could mean more opportunities for poaching. In a recent study we conducted (chapter 2), hunters in the RWRA showed a significantly higher inclination to poach than nonhunters.

One way in which people respond to human-wildlife conflict is by poaching, and prevention depends on determining what promotes this conflict, such as landscape features and intersections of humans and wolves (Treves et al., 2004). Enforcement of interventions that reduce poaching are challenging due to lack of spatially explicit information and little knowledge of stakeholder perceptions (Kahler et al., 2013). Being able to predict conflict locations, and prevent poaching can further reduce cost for conservation and landowners, possibly reducing political controversy in the process (Treves et al., 2004).

In human-dominated landscapes, the persistence of carnivore populations is the result of a complex interaction among several environmental and human factors (Llaneza et al., 2012). Spatially explicit analysis of ecological and social factors influencing survival has been used to create tools for conservation for a number of species including white-tailed deer (Haines et al., 2012), wolves in Switzerland (Behr et al., 2017), wolves in Spain (Llaneza et al., 2012), tigers in Nepal (Carter et al., 2012), and general wildlife poaching in Namibia (Kahler et al., 2013). These studies have provided a foundation for creating a method by which we can inform conservation efforts through predictive risk maps that are species-specific and localized in context.

Geospatial Theory

Spatial theory is the study of space and place and involves geography, the natural world, material objects, the built environment, social institutions, and others (Gunderson, 2014). Space is the physical setting in which everything occurs, and place is the outcome of the social process of valuing space, the humanized landscape. Social science data such as behaviors are spatial data when the location is known, because behaviors such as poaching occur at geographic locations. Spatial dependence may be shared attributes that produce clusters of behavior (such as shared income), or it could be shared behaviors because of proximity (such as neighbors talking). This proximity promotes interactions (Darmofal, 2015) such as between humans, and humans to wolves, promoting interactions between each other.

Habitat models have used spatially explicit techniques in conjunction with social data to identify protected areas, such as when Knight et al. (2010) assessed social factors hypothesized to define opportunities for conservation by individual land managers for a private land conservation program. They used data on vulnerability, economic data, and human activities that could compromise conservation. They believed choices made by managers, along with spatial patterns in nature, determined effectiveness of conservation measures. Castro et al. (2014), used spatial analysis to determine ecosystem service trade-offs. They emphasized the importance of using social and ecological data for this analysis since services are influenced by ecosystem properties and societal needs across the landscape. For poaching in particular, spatial analysis is valuable in developing risk maps for poaching locations. In Southern Spain, risk mapping was used to detect poisoning events. Results showed greater incidence of poisoning in avian and mammalian predator when those populations were correlated with areas of high predator richness and high wild rabbit hunting yield (Márquez, Vargas, Villafuerte, & Fa, 2013)

Traditionally, wildlife habitat suitability models have not used social attitudes as part of their spatial analysis, which has been a major limitation in determining suitable habitat (Behr et al., 2017).Wolves, however, move into areas occupied by humans, including areas owned by landowners whose understanding of nature does not include large carnivores. While ecological conditions may be favorable for wolves, human acceptance may be low and illegal killing behaviors may be the result. Researchers in Switzerland combined ecological data with social data to create a socio-ecological suitability model for wolves. In this study they created an acceptance layer by asking residents in wolf areas, “Are you in favor or against wild wolves living in Switzerland?” For their human acceptance model (HAM), they used geo-referenced predictors including human density, mean age, language, tourism intensity, small livestock, wolf distance, depredation, elevation, and agricultural areas (Behr et al., 2017). Their map resulted in a much-reduced area of suitable habitat for wolves, and their model agreed with current areas where wolves are successful. Their model could be useful to evaluate overall suitable habitat but also to predict range expansions and areas where intervention is needed for survival of species such as red wolves. What are the spatial attributes that promote poaching in the red wolf population in NENC and how do locations of attitudes influence risk of poaching in those areas? Where are the best locations for red wolf recovery based on spatial attributes such as land use? All of these are unanswered questions in the NENC red wolf population.

Research Question and Hypothesis

Addressing large carnivore poaching is challenging. Poaching risk is driven by various, interacting social and ecological variables at a range of scales, from individual red wolves to landscape levels (Carter et al., 2017, 2012), and research efforts to identify and minimize poaching risk can improve conservation outcomes.

Our goal was to conduct a spatial analysis that combines ecological and social risk factors to identify areas where wolves are most vulnerable to poaching in NENC in order to inform future management efforts. We identified environmental variables on the landscape that are associated with red wolf survival and combined them with results of an attitude survey (see Chapter 2) concerning red wolves and their conservation to test how they inform overall risk spatially. Specifically, we evaluated 1) whether attitude toward red wolves and acceptance for the red wolf reintroduction program correlate with documented poaching events, 2) where local residents perceive red wolves to be at risk of being poached 3) whether environmental variables of land cover, distance to public managed lands, distance to roads, deer density, and human population density are associated with poaching risk, and 4) how poaching locations change across the landscape during hunting season. Finally, we used logistic regression models to look for areas where red wolves are most likely and least likely to be poached to create a predictive layer of poaching.

Materials and Methods

Study area

Our study site consists of the five counties within the RWRA on the Albemarle Peninsula in NENC (Beaufort, Dare, Hyde, Tyrrell, and Washington counties) (Fig 1). Total human population for all five counties according to the North Carolina 2010 census was 105,124 (Census.gov), equivalent to the lowest population density for the state ("Population density of NC 2015," 2015). The population consists of 49.06% males and 50.93% females and has median age of 45.97 ("NC OSBM: LINC," retrieved 4/1/2019). The RWRA consists of 6,000 km^2 of private, federal, and state lands including four USFWS managed National Wildlife Refuges: Alligator River, Mattamuskeet, Pocosin Lakes, and Swanquarter, and a Department of Defense bombing range (Fig 2).

Land cover types for the RWRA include 40% woody wetlands, 26% cultivated crops, 16% evergreen forest, 5% emergent herbaceous wetlands and other minor (less than 5%) land covers of developed (open space, low and medium), barren land, deciduous forest, mixed forest, shrub/scrub, herbaceous, and hay/pasture (Homer et al., 2020).

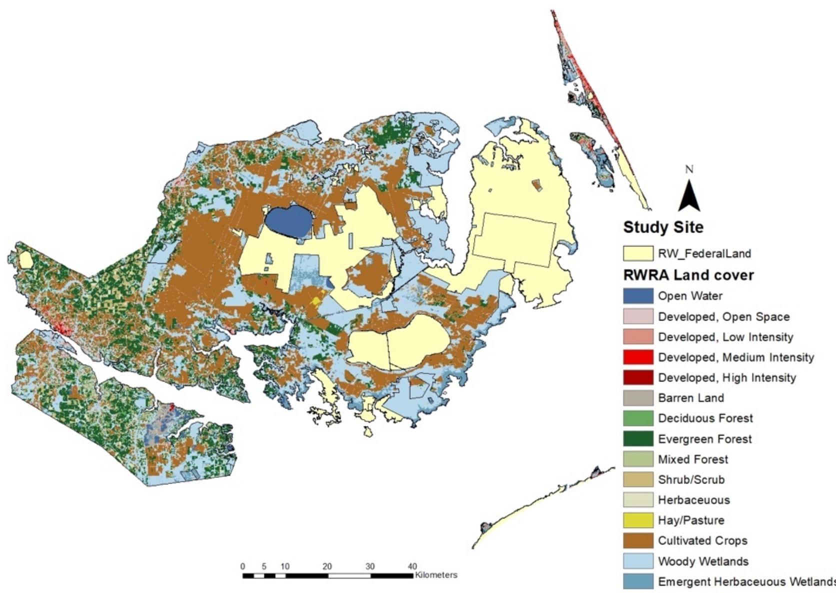

Fig 1. Study site showing the five-county RWRA including federal and state-owned lands and land cover types found throughout the area (Homer et al., 2020).

Data Collection and Analysis

Poaching Data

The USFWS has maintained a database of all red wolves in the RWRA since reintroduction began in 1987 (USFWS, 2018). This database contains information on trapping, tagging, and demographic and spatial information collected and maintained by USFWS personnel for a total of 810 red wolves including adults and pups (data through December 2018). USFWS red wolf database records include a suspected cause of death (COD), an official COD, necropsy results if performed for each wolf of known fate (final outcome) and location of COD or last known location for wolves that became fate unknown (FU). These data were collected by the USFWS through field work, reports from trappers, private citizens, mortality signals from radio-collars and others (USFWS, 2018). Our study included only those red wolves who wore mortality-sensitive radio-collars including both GPS and VHF collars monitored through twice weekly radio-telemetry flights and ground telemetry (Hinton et al., 2015). We mapped mortality data for 386 adult collared red wolves from this database for which spatial information was available (65 collision, 31 legal, 67 nonhuman, 81 unknown and 142 poached) and for 115 FU red wolves (see Chapter 1 for full method of calculating risk for different causes of death). We used the points in conjunction with the ArcMAP kernel density tool with 150 cell size to create a poaching density raster layer for other analysis.

Social Data

We used survey data gathered in NENC, which included 400 responses, to assess attitudes toward red wolves, and behavioral inclination toward them (see chapter 3 for complete method). For our spatial analysis, we analyzed two social assessments from this earlier study. Since our respondents were not representative of the area, we decided not to use attitude in this analysis. Rather we chose to use responses to our behavior question. On our survey, we evaluated the choice to kill a red wolf through question 11, which asked, “It is currently against the law for a private citizen to kill a red wolf except in defense of life (human, livestock, or pets). Are there any other situations you might try to kill a red wolf anyway (choose all that apply)?” Options included (1) “any wolf I encounter on my own”, 2) “the wolf did not run away from me when I was on foot”, 3) “the wolf did not run away from my vehicle”, 4) “the wolf was on my property”, 5) “the wolf came too close to my home”, 6) “the wolf approached my pet or farm animals”, 7) “I would not kill a red wolf”, 8) “I would support someone else killing a red wolf”, and 9) “other”. If the respondent chose any lethal situation, they were given a total value of one. We then totaled the number of respondents choosing a lethal response for each zip code and created a spatial layer in ArcMAP reflecting those values. We used this approach because it only takes one person to poach a red wolf, so even a total value of one, representing a respondent that said they would kill a red wolf for a zip code can be significant. Second, we used a behavioral inclination index described in chapter 3 for which we totaled the number of lethal responses for each respondent (values could range from 0-9 for reach respondent), such that a higher number of lethal responses indicating a higher behavioral inclination to poach a wolf. Again, we totaled the behavioral index for each respondent and each zip code. These values may be higher than the lethal approach described above because they represent an increase in the number of situations respondents said they would kill red wolves and may be more representative of risk. For both of our social variables, when there were fewer than three responses for a zip code, data was combined and averaged with adjacent zip codes within the same county.

One of our goals was to incorporate local perceptions of poaching risk to red wolves and so we mapped perception locations and compared them to documented poaching events in the RWRA. To find these locations, respondents were asked during the survey, “Where do you believe red wolves are most at risk of being killed?” and were provided with a map of NENC that they could click on and automatically record a latitude and longitude for their response. Alternatively, they could choose, “I don't know where red wolves are most likely to be killed.” Following they had the option of providing an explanation for their response by finishing the sentence, “This is a high risk area because..”. Perceptions points were used to create a density layer using the kernel density tool in ArcMAP with 150 cell size. We then distributed 142 random points (equal to the number of poaching events) across the 5-county RWRA to test for correlation between the poaching density and poaching perception density raster layers using the nonparametric Spearman's rank correlation since our data was not normally distributed.

Evaluation of environmental variables

We evaluated association between ecological and social attributes and different fates of red wolves in the current RWRA using the variables of land cover type, land management (public vs. private), distance to roads, deer density, deer harvest, human population, and hunting season. The selection of these environmental factors was based on attributes of red wolf survival and previous spatial studies (Behr et al., 2017; Kahler et al., 2013; Oeser et al., 2020; Rashidi et al., 2018; Treves et al., 2004).

Land cover

Identifying features of the landscape such as land cover type used by wolves is an important first step in determining where humans intersect with them. Using the National Land Cover Database (NLCD) 2016 land cover layer, we identified 13 land cover types used by red wolves, which we reduced to the 6 most represented types of open water, developed, evergreen forest, cultivated crops, woody wetlands, and other. We predicted that land cover with higher rates of poaching incidents would indicate areas with either higher levels of human-wolf interaction or areas targeted by poachers. Hinton et al. (2016) reported red wolves used agricultural areas more than any other kind of land cover followed by wetlands, coastal bottomland forests, and pine forests. Agricultural lands are also a resource for hunting game including white-tailed deer, turkey and other species found in NC (Knoche and Lupi, 2007), making these areas susceptible to conflicts between humans and red wolves. We assessed the land cover type found at each fate location and conducted chi-square analysis to test whether different fates occurred disproportionately in different land covers.

Land management

The RWRA was originally chosen as a site for red wolf reintroduction in part due to the amount of state and federal lands available on the Albemarle Peninsula. Those management areas are Alligator River National Wildlife Refuge (NWR) where red wolves were first released, Pocosin Lakes NWR, Mattamuskeet NWR, Swanquarter NWR, and Dare County Air Force Range. Since their reintroduction, red wolves have moved from federal and state lands to adjacent private property and eventually migrated throughout the RWRA. Also, Hinton et al. (2016) reported red wolves using edges of agriculture land and forested habitats, which is a prominent feature of public land borders. We determined distance from each red wolf mortality or FU location to the nearest management area with the ArcMAP analysis near tool and tested for variation between different fates using an Analysis of Variance (ANOVA) and Tamhane's post hoc test.

Distance to roads

Transient red wolves use roads extensively (Hinton et al., 2016a) and so these areas present another opportunity for human-wolf interaction, and easy access for would-be poachers (Haines et al., 2012; Hinton et al., 2016a). Using the road characteristic layer from NC Department of Transportation ("Road characteristics," 2020), we calculated distance to the nearest paved road using the ArcMAP analysis near tool. This layer includes only paved roads and so our analysis will not include distance to private dirt roads seen throughout the RWRA. We compared mean distance to roads for each of the 5 fates (4 CODs and FU) using a one-way analysis of variance (ANOVA) and Tamhane's post hoc, and then compared poached locations to locations of all other fates pooled together using a t-test.

Deer density and deer harvest

From our 2018 interviews, deer emerged as an important factor in red wolf conservation. Participants explained the importance of deer hunting for both recreation and food and also used their land as hunting leases for local and out-of-town hunters. Since white-tailed deer account for the majority of red wolf diet (Dellinger et al., 2011; McVey et al., 2013), and red wolf poaching increases significantly during hunting season, we used 1) deer density for the RWRA (USDA, 2008) and 2) the number of deer harvested in each county as predictive layers for poaching.

Our deer density spatial layer consisted of polygons showing deer density at 1) less than 15 mi^2, 2) 15 – 30 mi^2, 3) 30 – 40 mi^2, and 4) more than 45 mi^2. We tested for differences in poached and non-poached areas in each of these different deer densities using chi-square analysis.

Deer harvest data was collected from the NC Wildlife Resources Commission, which reports the number of deer harvested for each county/year. We used data from the 2017-2018 season to coincide with our social data collection and included all deer (antlered bucks, button bucks, and does) harvested (NCWRC, 2017). The amount of deer harvested at each event location was determined by the county the event was located in. We tested for differences in poached and non-poached areas in each of these different deer harvest using chi-square analysis.

Human population

The RWRA has the lowest human population density for the state of NC ("Population density of NC 2015," 2015). We evaluated both human population totals and density per square mile data from NC OneMap, provided for each zip code, to join with fate data and determine the population density at each wolf mortality point. Using the nonparametric Kruskal Wallace equality-of-populations rank test, we tested whether different fates occurred in areas of different human population.

Hunting season

Red wolf survival decreases significantly during hunting season months of October through December (Hinton et al., 2016b)(Agan, Chapter 1) and wolves disappear, becoming FU at a higher rate during these months than at any other time of the year. We separated poaching incidents on the landscape into those that occurred during hunting season and nonhunting season and conducted a chi-square analysis using zipcode to test for differences in locations of poaching during these two time periods. The same test was conducted for FU wolves.

Construction of risk model and map

We created a model of poaching risk using logistic regression and ArcGIS Spatial Analyst to predict areas of high and low poaching risk for red wolves in the NENC RWRA. Our model was based on the investigation of the relationship between each variable described above and the USFWS poaching database. Poaching events included 137 observed poached and 112 FU wolves we classified as cryptic poached (chapter 1, scenario 2 for cryptic poaching risk). We compared these to the locations of other causes of death to identify attributes of areas where wolves are more likely to be killed by poaching rather than by another cause. First, we attributed locations of 249 poaching events (coded 1) and 159 other causes of death (collision, legal, nonhuman) (coded 0) with nine environmental and two social predictor variables: human population, deer density, deer harvest, % cropland within 500m, % forest within 500m, % developed within 500m, % other cover type within 500m, distance to nearest paved roads, distance to nearest management area, lethal choice and behavioral inclination index. Both simple and quadratic models were assessed when a variable appeared quadratic. Before including a predictor in our model, we used univariate logistic regression for each to test for significance, determine the receiver operating characteristic curve (ROC), and make sure the standard error was smaller than the coefficient. We also tested for collinearity between all variables and if two variables were collinear, we used the one with the higher ROC as suggested by Treves et al. (2011) or tested both for fit individually when the ROC difference was less than two. Deer harvest was collinear with distance to management area, and our two social variables of behavioral inclination and lethal response were collinear. Out of 13 initially considered predictor variables, 7 met our requirements for the next step.

We used multivariate logistic regression in STATA (StataCorp, 2019) to evaluate predictor variables using a stepwise approach. We began with the strongest predictor variable with the highest ROC, deer harvest, and added each additional variable in order of ROC until we selected the top model with the highest predictability determined by both ROC and Akaike Information Criteria (AIC). We then calculated model fit statistics (AIC, BIC) for the final model, and used a chi-square goodness of fit test to evaluate model fit. Once our model was finalized, we created a second model that evaluated only observed poaching (1) with other COD (0) to distinguish any variables that might be attributable to cryptic poaching (FU) and not observed poaching.

To create a final risk map in ArcMAP, we converted each variable to a raster format map layer with a 30 m cell size and calculated the relative probability of poaching at each cell using the map algebra tool in the Spatial Analyst toolset of ArcMAP with the parameter estimates from the final model in the following equation:

$$P = \frac{e^{a+b_1X_1+b_2X_2\dots}}{1+e^{a+b_1X_1+b_2X_2\dots}}$$

Where P represents relative probability of a poaching event occurring on that cell, *a* represents the intercept, *b* values represent parameter estimates, and *X*s are the values of each variable for the cell (Fig 2). The result produced a relative risk scale of 0-1 with low values being low risk and high values high relative risk.

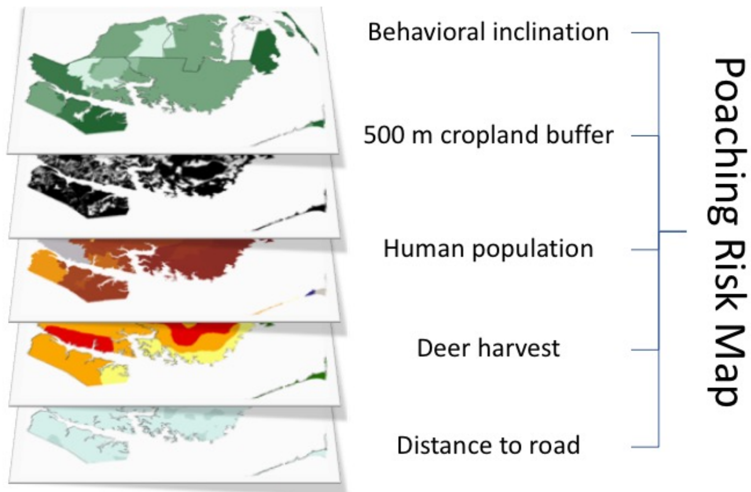

Fig 2. Model development. Intersection of five independent variables used in final risk model.

We conducted all analysis in STATA IC 15.1 for Mac (StataCorp, College Station, Texas, 2019) or RStudio (RStudio Team, 2020) and the statistical software R (R Core Team, 2018).

Results

Poaching density

Poaching density is highest in two distinct areas. The first is in southwest Washington county, zip code 27970 and adjacent to the northwest border of Pocosin Lakes NWR. The second hot spot is in northeastern Hyde county, zip code 27824 and situated between the southern end of Alligator River NWR and the northeast side of Mattamuskeet NWR. The majority land cover for both areas is cultivated cropland.

Predictor Variables

Social variables

A two-sample t-test to compare means for any lethal choice with poached locations (mean = 0.64) and other COD (mean = 0.42) showed significant differences ($t = -6.04$, $P < 0.001$). Test for behavioral inclination was similar showing significant differences between poached locations (mean = 1.19) and other COD locations (mean = 0.78)($t = -3.79$, $P < 0.001$) with poaching events more prominent in zip codes where respondents showed an increased inclination to kill a red wolf. Both social variables were mapped at the smallest possible scale of zip code, which residents identified on their surveys (Fig 3).

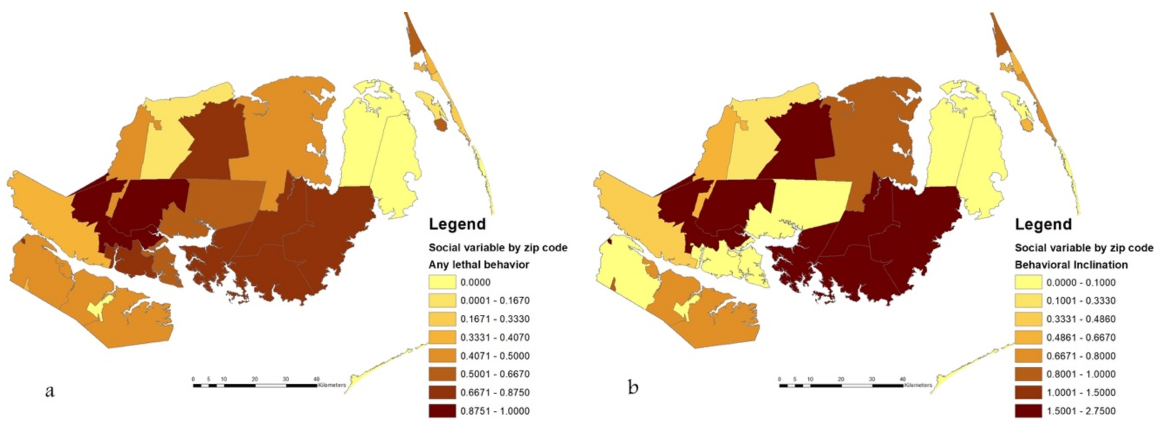

Fig 3. Social variables a) number of respondents choosing any lethal behavior and b) total behavioral inclination index in the RWRA by zip code.

For poaching perception, there were 213 responses with an included location (Fig 4) and 121 comments regarding why they chose those locations. Some of those comments referenced the amount of farmland providing activity for wolves, large numbers of hunters in the area, contact with humans, traffic, human contact with wolves along the edge of refuges, lack of respect for the law and animal rights, previous sightings, remote areas, residential areas, and simply because that's where red wolves are. Density of actual poaching events show significant positive correlation to public perception of where red wolves are most likely to be killed (Spearman's rho = 0.55, $P < 0.001$). Correlation appears to vary by scale. At a broader scale, the correlation between shaded areas is strong, however at the finer scale, higher levels of poaching are concentrated in slightly different areas (e.g., south central Washington County and northeastern Hyde County) than where people perceive poaching risk (southwest and northeast Tyrell County).

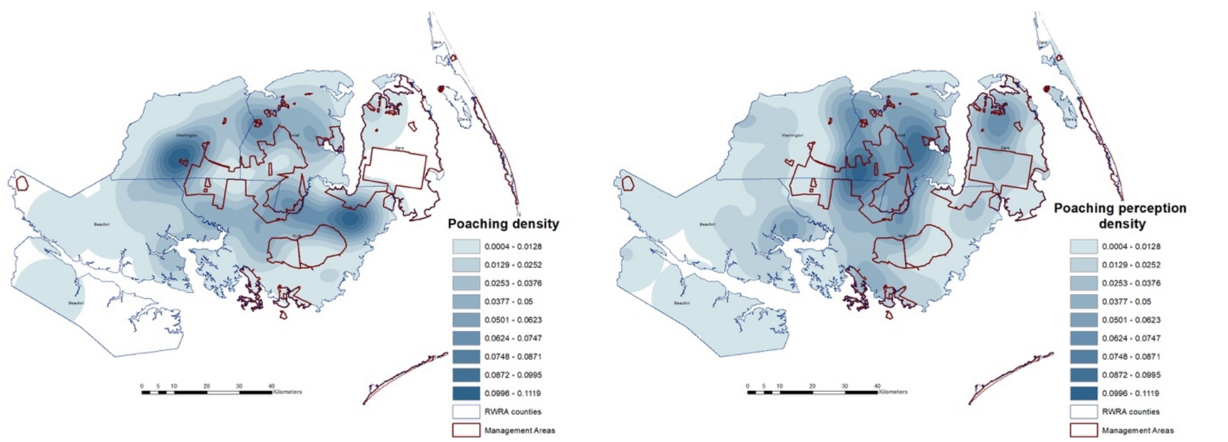

Fig 4. Kernel density for a) historical poaching events and b) perception of where red wolves are most likely to be poached.
Density results are number of poaching events per km^2.

Land cover

There were significant differences in the proportion of each fate found in different types of land cover ($\chi^2 = 116.6$, df = 25, $P < 0.001$) (Fig 5). The highest percentage of nonhuman deaths were found in woody wetlands followed by cultivated crops, the two most represented areas of land cover found in the RWRA (Table 1). Unknown fates, unknown deaths and poached locations show the opposite trend with the highest percentages in cultivated crops followed by woody wetlands and collisions occur predominantly in developed areas.

Table 1. The percentage of each fate that was found in each land cover type.

The two most abundant land cover types in the RWRA are woody wetlands (40%) and cultivated crops (26%).

	Fate					
	Collision (n=65)	FU (n=113)	Legal (n=30)	Nonhuman (n=65)	Poached (n=141)	Unknown COD (n=81)
Land cover type	%	%	%	%	%	%
Open water	0.0%	0.9%	3.3%	10.8%	0.7%	2.5%
Developed	49.2%	8.8%	13.3%	6.2%	17.7%	3.7%
Other	7.7%	8.8%	0.0%	4.6%	2.8%	4.9%
Evergreen forest	1.5%	6.2%	3.3%	4.6%	6.4%	2.5%
Cultivated crops	21.5%	45.1%	40.0%	27.7%	45.4%	51.9%
Woody wetlands	20.0%	30.1%	40.0%	46.2%	27.0%	34.6%

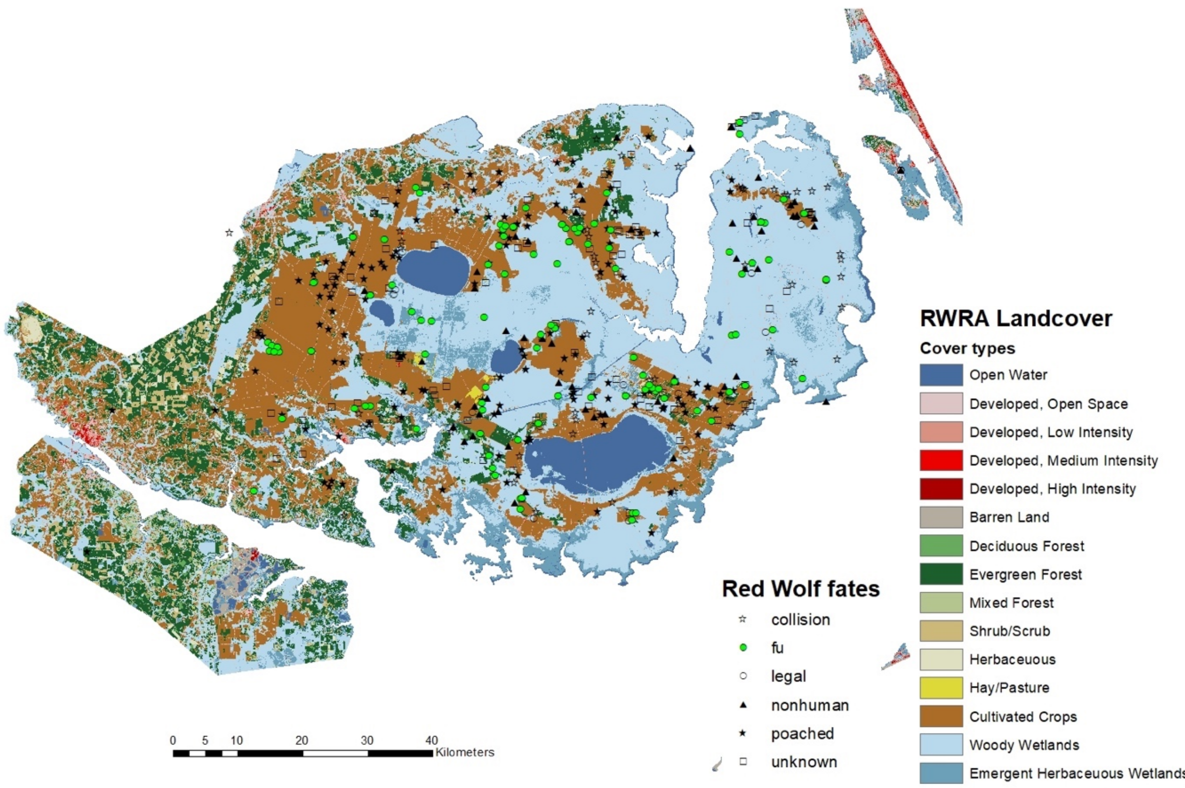

Fig 5. RWRA with fate locations overlaid on land cover types.

Land management

Locations of fates were at significantly different distances from the nearest management area (federal and state public land) according to ANOVA ($F(5,494) = 4.69$, $P < 0.001$) (Fig 6)(Table 2). Tamhane's post-hoc test revealed legal and nonhuman were both significantly closer to management areas than unknown COD, FU, and poached (95% confidence interval did not include zero).

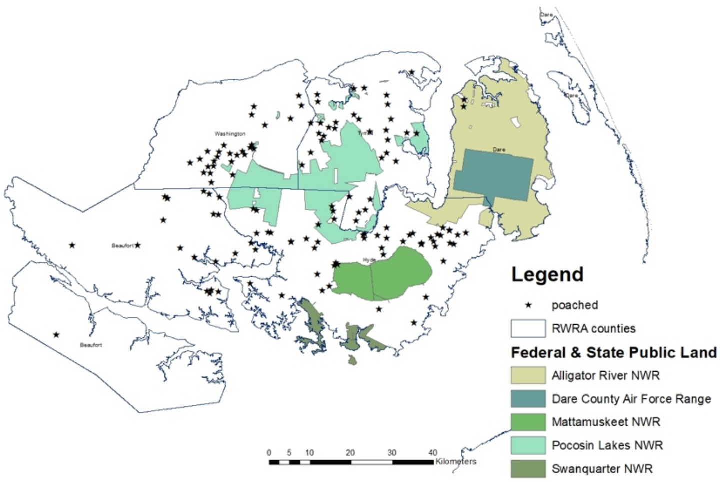

Fig 6. Federal and state public lands in the RWRA compared to locations of poaching events.

Table 2. Distance to nearest road and management area (MA) in meters for each type of fate.

	Distance to road (m)			**Distance to management area (m)**		
Fate	Mean	SE	95% CI	Mean	SE	95% CI
Collision	111.5	36.8	38.1, 185.0	2797.1	504.1	1790.0, 3804.2
Poached	636.2	62.2	513.2, 759.2	5593.0	838.3	3935.8, 7250.2
Legal	633.8	126.2	376.1, 891.5	1489.0	345.0	784.4, 2193.6
Nonhuman	1192.8	172.7	848.1, 1537.5	1734.6	268.7	1198.2, 2271.1
Unknown	1158.7	158.5	843.3, 1474.2	4436.7	759.7	2924.9, 5948.5
FU	1643.6	151.2	1344.1, 1943.1	3226.9	452.6	2330.2, 4123.6

Distance to roads

There were significant differences in the distance from roads between the fates ($F(5,494) = 17.99$, $P < 0.001$) (Table 2). Tamhane's T2 post-hoc showed collision as significantly closer to roads than all other fates and FU was significantly farther from roads than both poached and legal (95% confidence interval did not include zero). A t-test for unequal variance showed poaching was significantly closer to roads than all other fates pooled ($t = 4.60$, $P < 0.001$) with a mean distance of 636m (vs. 1084m for other fates) and observed poaching (636m) was significantly closer to roads than cryptic poaching (FU) (1643m) ($t = 6.03$, $P < 0.001$).

Deer density and deer harvest

Deer density in the RWRA was represented in the USDA deer density layer (USDA, 2008) by areas of less than 15 deer per mi^2, 15-30 per mi^2, 30-40 per mi^2, and more than 40 per mi^2. We assessed presence/absence of poaching events in areas of different density (Fig 7). Only 16 poaching events (11.8%) occurred in areas with less than 30 deer per mi^2, while the remaining 119 events in areas with greater than 30 deer per mi^2. This ratio was significantly different compared to that of non-poached mortality locations where 32% occurred areas of lower deer density (χ^2 = 35.1, df = 4, P <0.001).

Deer harvested for 2017-2018 totaled 133 in Dare county, 574 in Tyrell county, 1074 in Hyde county, 1240 in Washington county and 2562 in Beaufort county. There were significantly more poached red wolves than other fates in those counties with higher rates of deer harvest (χ^2 = 63.76, df = 4, P <0.001).

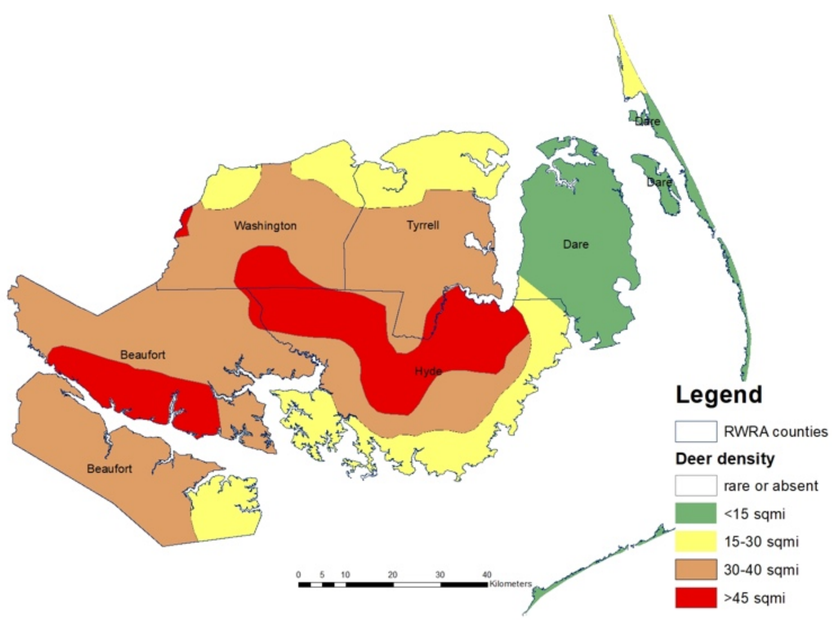

Fig 7. Deer density in the RWRA. (USDA, 2008)

Human population

Human population density was significantly different between fate locations using the Kruskal Wallace equality-of-populations rank test (H(5) = 27.26, $P < 0.001$). Poached, unknown COD and FU all occurred in similar, higher human population density, while collision, legal, and unknown were found in lower human population densities (Table 3).

Table 3. Average human population density for each fate.

	Human population per square mile	
Fate	Median	IQR
Collision	8.32	6.83, 12.09
Poached	11.46	11.36, 19.15
Legal	8.32	7.03, 11.46
Nonhuman	8.32	7.03, 12.09
Unknown	11.36	6.83, 19.15
FU	11.36	7.03, 12.09

Hunting season

Poaching occurred in different zip codes during hunting season and non-hunting season ($\chi^2 = 31.47$, df = 1, $P < 0.001$). We then ran a more detailed chi-square by testing each zip code with hunting/non-hunting season with a more conservative alpha of 0.01. For two of the 42 zip codes in the RWRA, poaching increased significantly during hunting season. Both were located in Hyde county including zip codes 27826 with 2 poaching events outside hunting season and 11 during ($\chi^2 = 8.67$, df = 1, $P = 0.003$), and 27810 with 3 events outside and 19 during ($\chi^2 = 12.48$, df = 1, $P < 0.001$).

Differences in disappearance events (FU) did not differ significantly during hunting season when tested by zip code ($\chi^2 = 0.81$, df = 1, $P = 0.37$).

Poaching Risk Model

The top ranked logistic regression model included the predictor variables deer harvest, human population, distance to roads, % cultivated cropland within 500m and behavioral inclination. Model ROC = 0.72, AIC = 487.7, BIC = -39.9 and goodnesss of fit χ^2 = 390.1, P = 0.35.

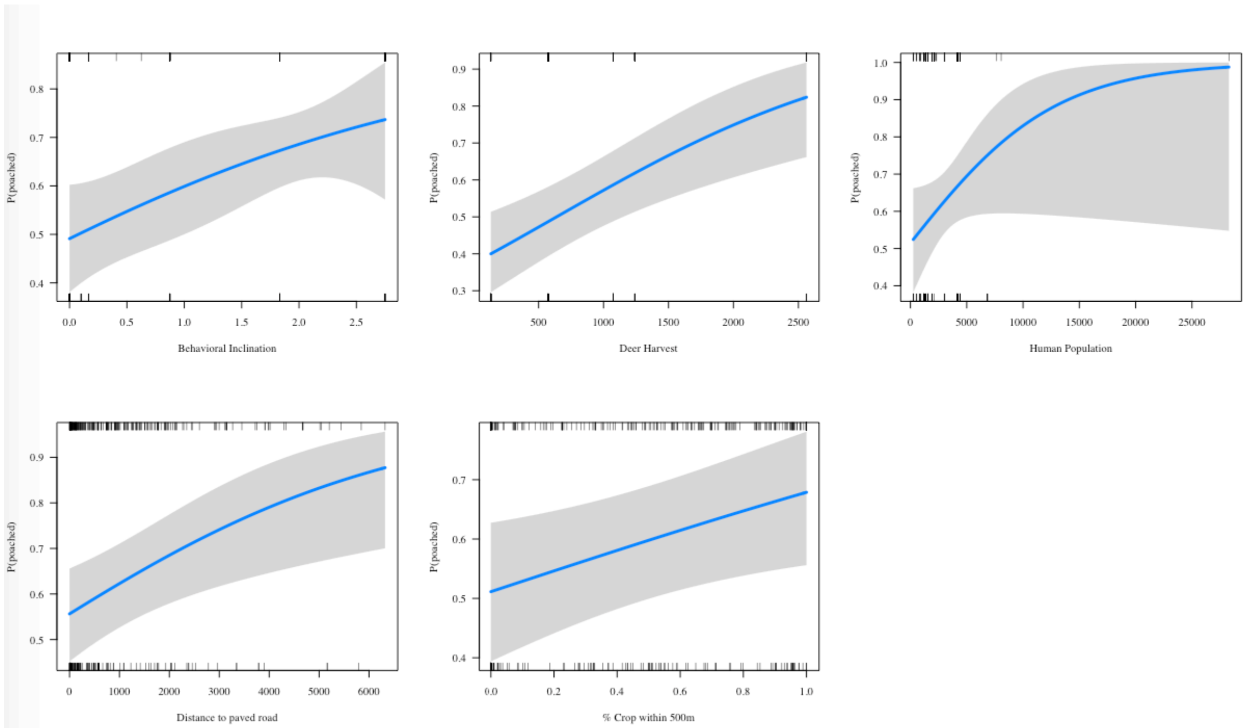

Fig 8. Added variable plots from the final model showing relationships between relative probability of being poached at a location and each of the 5 predictor variables of behavioral inclination, deer harvest, human population, distance to roads, and percent cultivated cropland.

Table 4. Variables and their estimates from the final logistic regression model, used to create a map of relative poaching risk.

Variable	Estimate	SE	Z	P
Deer harvest	0.000792	0.0002216	3.61	<0.001
Cultivated cropland	0.7065419	0.3061773	2.31	0.021
Distance to roads	0.0002757	0.0000958	2.88	0.004
Human population	0.0001555	0.0000823	1.89	0.059
Behavioral inclination	0.4016551	0.1410326	2.85	0.004

The poaching risk map for the RWRA shows highest risk areas in the west side of the RWRA and north of Pocosin Lakes NWR (Fig 11). Other areas of high risk are found throughout the area with smaller bands running southwest of Alligator River NWR and along the edges of Mattamuskeet NWR.

Observed differences between the model containing all poached wolves (including cryptic poached locations) and the model with only observed poached wolves shows major differences inside the refuges where risk is much lower for observed poached wolves. Distance to roads was the variable that made the most significant difference in the two models with cryptic poached events found significantly farther away from roads than observed poached events.

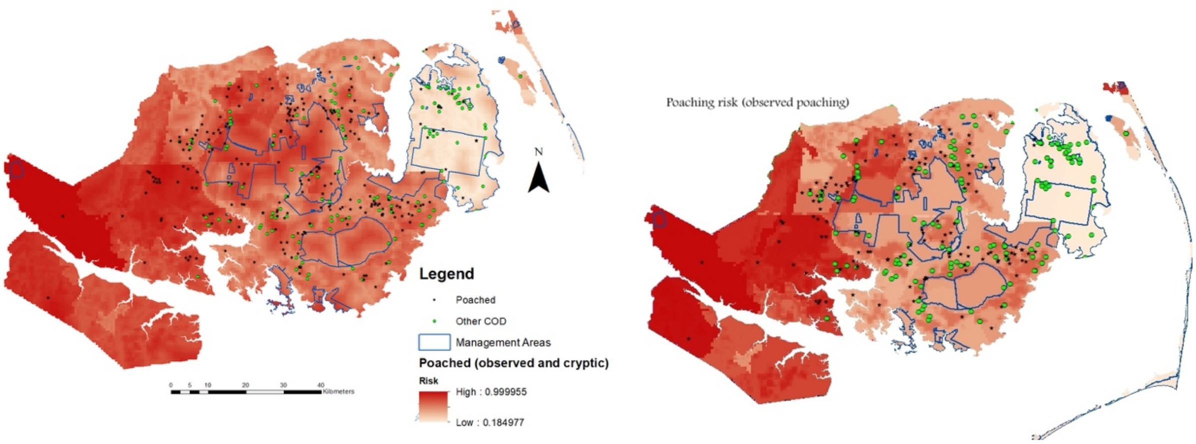

Fig 9. a) Final poaching risk map with poaching events (observed and cryptic), b) risk map with only observed poaching risk, and other COD overlaid for visual comparison.

Discussion

Our predictive model of poaching performed well at predicting poaching events in the RWRA. Those red wolves that move west, migrating from management areas are increasingly more likely to be poached until an area is reached where they are either poached or they disappear (cryptic poached), and they no longer die from other causes. It is widely accepted that correlation in risk maps such as this does not allow us to make claims about underlying cause (Kraemer et al., 2019) rather they are only meant to show correlation between independent variables and poaching events. Through our analysis, correlations between our 5 variables and poaching estimate a high level of predictability with an ROC of 0.72.

Local risk perception, as identified via survey results from local residents, though correlated with actual poaching events, was focused more inside management areas of Alligator River NWR and Pocosin Lakes NWR while actual poaching events are more peripheral. Distance to these management areas proved to be an important variable showing poaching risk to be close to the outer edge but not inside. This is in contrast to red wolves with nonhuman deaths, which were found both inside and outside these areas. The significant correlation between perception and actual poaching events was unlike results from Kahler et al (2013) who reported that poaching events and stakeholder perceptions of where poaching occurred were not spatially correlated. However, for their study, the locations of documented poaching events were spatially correlated with areas that stakeholders perceived wildlife as a threat to their livelihoods. Future research in NENC involving local perception could use more specific questions of risk such as threats to livelihood, risk to other wildlife, low risk of getting caught and other reasons respondents gave in our survey.

Our survey did not include a representative sample of the residents of the RWRA and so behavior variables used in this analysis are only representative of those who completed the survey. Attitude and behavior measures still need considerable research to determine the best possible methods and results from such surveys should be considered carefully as would-be poachers may not complete attitude surveys and it only takes one person to kill a red wolf. For that reason, we chose to use behavioral inclination for our risk map because it shows areas where individuals have said they would kill a red wolf for an increasing number of reasons. We were unable to be more precise spatially because our survey only identified zip code and so risk is placed over a larger area than individual responses would justify. Also, people can move between zip codes and so residential location may not reflect the same location for which poaching may occur. In the future, surveys with more respondents that allow for more precise location residence, as well as questions that ask about where they would poach red wolves would increase confidence in these responses. People, hunters in particular, may move and encounter red wolves outside of where they live. Poachers may also be represented in other stakeholders, not just landowners in NENC, who travel to NENC for hunting opportunities. This type of data may therefore be most useful in identifying locations to build relationships with landowners and increase awareness of legal implications for poaching. We also recommend research on place attachment as part of identity for spatial analysis (Stedman, 2002). Ryden (1993) added that "through extensive interaction with a place, people may begin to define themselves in terms of…that place, to the extent that they cannot really express who they are without inevitably taking into account the setting that surrounds them as well" (Ryden, 1993). As each place has a unique culture, a greater understanding of spatial identity for the RWRA could help tailor how conservation efforts are implemented.

Poaching events were closer to paved roads than all other fates except legal and collision making it an important part of our risk model by distinguishing it from nonhuman, unknown COD and FU. This supports the notion that poachers use roads, which offer several advantages including access and escape (Haines et al., 2012). Collision events, while normally assumed to be non-intentional, may include some wolves that were targeted by drivers and so our number of poaching events may be an underestimate if some of those collisions were intentional. Although the NC DOT layer included only paved roads, there are many dirt roads throughout private lands, particularly in agricultural areas in the RWRA that were not included. Some poaching events were located adjacent to these dirt roads, suggesting they may lead to higher human/wolf interaction and opportunity for poaching. While poaching had a shorter distance to road value than most other fates, and FU had the longest, we believe that proximity could be even less if these dirt roads were included. Evaluation of the most current satellite imagery to map these roads would provide a stronger analysis of that data.

Cultivated cropland makes up 26% of land cover in the RWRA and had the highest poaching risk value of any land cover type. It was the top land cover type not only for poached wolves but also for unknown COD and FU. Red wolves may spend a lot of time in these areas before crops are harvested because their main source of prey, white-tailed deer, can also be found in these fields. Cropland is also used by landowners for hunting, both personal use and as hunting leases. This increases the opportunity for poaching since carrying firearms adds ability to opportunity. While deer density is highest for the RWRA in both management areas and on adjacent private lands, poaching only occurred in adjacent areas, suggesting that the combination of deer density and hunting on private lands is an important indicator of poaching potential. High numbers of deer can contribute to excessive crop loss for farmers (Côté et al., 2004; Stewart et al., 2007), and the presence of wolves is known to alter the behavior of deer and elk, causing them to change their habitat selection in response to wolves (Manning et al., 2009; Mao et al., 2005). In Hyde county alone in 2012, there were 107,559 acres of cropland in production with a market value of $133,411,000 ("2017 Census of Agriculture, NC State Profile," 2017), making agriculture a large part of the economy on the Albemarle peninsula. Red wolves spend time in agriculture fields (Hinton et al., 2016a) potentially decreasing crop losses and by working with landowners through education and conservation initiatives, both goals of decreasing red wolf poaching and reducing impact to crops by deer can be achieved.

Poached, unknown COD and FU occur more frequently in areas with higher human population density, compared to other causes of death. However, the Albemarle Peninsula still has the lowest population density for the state of NC and median density for these three fates was only 11.36 people mi^2 compared to 196 people mi^2 for the state (Population division, 2017). This suggests that while red wolves may attempt to avoid people by inhabiting areas of low human density, they are more likely to be poached where people are.

In chapter one, for scenario two of poaching estimation, we assumed all FU wolves were lost to cryptic poaching. In our spatial analysis, we compared poached locations to FU locations for each of our variables to determine if this assumption was supported. We also evaluated unknown COD, which could also include poached red wolves. Distance to roads was significantly less for poached wolves and greater for FU wolves, which could be the result of access or that poaching detection decreases as distance from roads increase; wolves poached closer to roads may be more likely to be discovered. Distance to management areas were also significantly different between fates with poached, FU and unknown COD being similar and the three most distant, perhaps because people believe poaching will go undetected on private land. Poached, FU and unknown COD locations occurred in similar land cover types with the highest percentage in cultivated crops and then woody wetlands, which was different from all other fates. The three fates had the highest percentage of locations (> 76%) in deer densities of greater than 30 deer mi^2 and were found in similar human population densities, which were significantly higher than all other fates. These similarities in location, along with the fact that FU events are the only other event increasing (though not significantly) during hunting season, support our idea that many FU locations may represent poaching events as suspected. Though we have analyzed similarities between these three fates, we chose not to include unknown COD in our final model raster surface since those fates could consist of any unknown value of FU, poached, collision or nonhuman deaths.

A limitation to this data is that FU locations only represent where the red wolf was last seen, not necessarily where it died. We are also aware that the hypothesis that all FU wolves are cryptically poached is an extreme estimate of poaching for this particular fate. However, it underestimates poaching that may be represented in the unknown COD and collision fates. In our poaching data analysis, this scenario gave us a midpoint of poaching risk, only slightly higher than the minimum risk and lower than other poaching studies (Ericsson and Heberlein, 2003; Treves et al., 2017b). At the very least, closer scrutiny as to why these wolves disappear may reveal environmental variables contributing to their loss and aid in the conservation of this species.

Our objective was to use spatial modeling to create a predictive map showing potential risk for poaching throughout the RWRA so that wildlife managers can tailor conservation interventions appropriately. We were able to spatially describe poaching activity patterns and the similarities and spatial characteristics between those wolves that were poached and those that became FU support our hypothesis that a large percentage of these wolves represent cryptic poaching events and should be monitored appropriately. These results can aid in surveillance efforts to mitigate poaching activity. Determining what those interventions should be is beyond the scope of this study, but should include research on what has worked in other carnivore management programs. The addition of spatial analysis in this process can show areas where management may have been more or less successful in the past and give insight into future decisions. Our results suggest human-wolf interactions are spatially associated with landscape characteristics that are appealing to both species and that social variables such as attitude and behavioral inclination can strengthen the predictive power of models describing those interactions. Using research that considers both environmental and social variables such as ours can provide guidance for outreach efforts to better understand where hostility may occur and why. The limited response we had to our survey may suggest difficulty in outreach efforts as there are likely a wide variety of attitudes in close proximity, which also may change over time. However, with limited resources, spatial data from studies such as this can provide managers with a good place to start.

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Chapter 5: Conclusion

Previous work, coupled with new calculations from this study that re-examine the level of poaching, make it explicitly clear that aggressive interventions must happen to reduce poaching immediately if there is going to be any chance the remaining 19 red wolves can create a self-sustaining population. In their most recent 5-year review completed in 2018, the USFWS recommended the red wolf retain its status as endangered under the ESA (St. John et al., 2015). While there have been significant changes in the RWRA since reintroduction began, such as the migration of coyotes into the area and problems with poaching, the area still retains most of what made it appealing for reintroduction in the first place including low human density and suitable habitat. With the Red Wolf Adaptive Management Plan (Rabon et al., 2013), the USFWS took an aggressive and successful approach to the encroachment of coyotes and should do the same with poaching. Research in other regions has demonstrated that wolves can successfully re-establish, both naturally and through reintroduction, where they once were extirpated in the wild including gray wolves in Yellowstone (Smith et al., 2003), gray wolves in Wisconsin (Treves et al., 2017) and Mexican wolves in Arizona and New Mexico (Hendricks et al., 2016). Implementing proven practices that prevent poaching or hasten successful reintroduction can reverse the trend of a decreasing NENC red wolf population and once again allow red wolves to thrive, not only in NENC but additional future reintroduction sites.

We found that anthropogenic causes of death are responsible for 0.724 – 0.787 of all red wolf deaths, with poaching (observed and cryptic) representing 0.51 – 0.635. Our results for risk of various causes of death, when compared to previous published estimates, support the need for including unknown fates in risk estimates. All anthropogenic CODs shorten the time that red wolves spent in the wild until they died or disappeared compared to those dying a natural death.

This early removal of red wolves would be expected to lower both birth rate and growth rate for the wild population. With such a small population, the loss of just one breeding wolf can have important negative effects on the wild population.

Understanding how people think about red wolves and their conservation is critical for conservation efforts and interventions. The USFWS explicitly states that the current regulations are not effective in fostering coexistence between people and red wolves (Kurth, 2018). However, in our study we found a majority of respondents had positive attitudes toward both red wolves and their conservation and those who dislike them are in a small minority. While other wolf studies have shown declining tolerance for wolves over time (Treves et al., 2013), our study showed consistently positive attitudes toward wolves and their conservation when compared to earlier data collection. However, even though the red wolf recovery program was implemented over 30 years ago, and red wolves are a high profile and controversial species, salience was low for some residents of the five-county area, and neutral attitudes toward red wolves ranged from 40% in Tyrell county to 15% in Hyde county. Attitude and behavior measures still need considerable research to determine the best possible methods, and results from such surveys should be considered carefully, especially when they are not representative of the local population as was the case here.

Would-be poachers may not complete attitude surveys and it only takes one person to kill a red wolf, therefore continued research will be needed to learn more about proximal mechanisms of poaching. Fifty-five percent of our respondents responded that they would not kill a red wolf in any situation. While promising, that means that there is still 45% that reported lethal behavioral inclination toward a red wolf, the majority being if the wolf approached their pet or farm animal, similar to other wolf poaching research (Browne-Nuñez et al., 2015). In our study, male hunters had the highest mean behavioral inclination to poach, the lowest level of acceptance of any stakeholder group and more red wolves are poached during hunting season than any other time. Other studies have shown similar population declines during this same time period in red wolves (Hinton et al., 2016), gray wolves (Treves et al., 2017), and coyotes (Chamberlain & Leopold, 2001). Our in-depth interviews revealed the amount of complexity involved in both attitudes and behavior toward a predator such as red wolves.

Across North America, success of carnivore populations has been linked to management policy and enforcement (Linnell et al., 2001) and managing wolves successfully, by protecting wolves and encouraging acceptance, is one way to generate support for their restoration (M. K. Phillips et al., 2003). The new USFWS red wolf policy proposal would limit protections of red wolves to federal lands on the Albemarle Peninsula, allowing take of red wolves on private land, and we found limited support for this policy that would allow the killing of red wolves on private property. Rather, in order to maintain viable population sizes in the region, the USFWS will need to implement and enforce favorable policy that prohibits take of red wolves that is consistent, clear, and protects wolves throughout the entire red wolf recovery area. The current designation of nonessential experimental population allows the USFWS to remove wolves for any reason at the request of landowners, which should reduce the incidents of illegal killing in those cases but only if landowners are aware of policy and have the resources for communication. With the number of "I don't know" responses regarding policy in our survey (42% of all respondents), there is room for more communication and education. Because approximately 76% of the RWRA is private, any anti-poaching measures implemented in NENC must be proven to work on private lands and should include programs that reward the presence of wolves, thereby increasing their value to local residents. According to one wildlife manager, ''the recovery of the species is not dependent on the setting aside of undisturbed habitat, but rather on overcoming the political and logistical obstacles to human coexistence with wild wolves.'' (Phillips et al., 1995)

Most of our participants shared frustration for the continued lack of communication between managers and the residents who are living with red wolves. During our interviews every person related a positive relationship to USFWS personnel with their acceptance of red wolf conservation even with their questions and/or dissatisfaction with how reintroduction took place. Even though trust for the USFWS scored high in our survey, responses such as this show that policy and program details could be better communicated with private landowners. Previous wildlife studies in NC concluded management considerations and decision making would need to include local and regional attitudes (Daley et al., 2004). How attitudes change in the future may depend on those decisions made by agency personnel who would benefit from a more inclusive decision-making process with stakeholders. Our study highlights the importance of relationship between agency personnel and landowners, not only in response to wolf-human interactions but throughout the entire process of recovery, including decision-making.

Our final objective was to use spatial modeling to create a predictive map showing potential risk for poaching throughout the RWRA so that wildlife managers can tailor conservation interventions appropriately. We were able to spatially describe poaching activity patterns. The similarities and spatial characteristics between those wolves that were poached and those that became FU support our hypothesis that a large percentage of these wolves represent cryptic poaching events and should be monitored appropriately. Our results suggest human-wolf interactions are spatially associated with landscape characteristics that are appealing to both species. Using research that considers both environmental and social variables such as ours can provide guidance for outreach efforts to better understand where hostility may occur and why.

Using mixed methods research proved to be beneficial at all stages of our study. The complexity of wolf behavior, human attitudes, and an ever-changing environment will continue to drive red wolf conservation and the need for research that is interdisciplinary and involves reconciliation ecology to conserve species within these human-dominated landscapes.

Fragmented protected areas such as those found in the North Carolina red wolf reintroduction area, are unable to contain large carnivores who will disperse into surrounding land, seeking territory as the population grows. As red wolves continue to move outside of protected boundaries and onto private lands, poaching may continue to be a problem impacting wolf populations and increasing social conflict in the area. Whether recovery in North Carolina is a success or failure, we need to understand how management can be improved in the future based on the experience of those from the past and present recovery areas. Should red wolves be reintroduced into new sites in the U.S., as goals for the red wolf recovery plan mandate, managers need to understand who is poaching, why they poach and why the problem continues to persist in order to make good decisions for future recovery of the species. Our study revealed that even with high acceptance and positive attitudes, anthropogenic mortality including poaching is still the number one threat to red wolf survival.

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Appendices

Appendix A: Informed Consent

TITLE OF STUDY
Survey of attitudes related to red wolves

PRINCIPAL INVESTIGATOR
Suzanne Agan
Antioch University New England
Environmental Studies
40 Avon St, Keene, NH 03431

DESCRIPTION OF THE RESEARCH

You are invited to participate in a research study about red wolves. We are interested to know your views about red wolves in North Carolina to continue to guide policy makers and other groups who may be involved in red wolf recovery.

You have been asked to participate because you are a hunter or own hunting land on the Albemarle Peninsula. As someone who is out in nature more you may have had an opportunity to hear, see or discuss wolves with other people. I'm interested in learning what you and others think about red wolves as well as your direct and indirect experiences you have had with them. Your answers are completely confidential. Your responses will be kept separate from all personal information such as mailing address and name, and no one will contact you regarding your responses.

The purpose of the research is to learn how people experience red wolves on the Albemarle Peninsula. It is my hope that this research can help inform policy makers and wildlife and conservation managers' work with red wolves.

WHAT WILL MY PARTICIPATION INVOLVE?

If you decide to participate in this research, you will be asked to complete an approximately one-hour face-to-face interview with myself, the principal investigator. My goal is to interview you at a time and place that is most convenient for you.

ARE THERE ANY RISKS TO ME?

You may be asked to provide confidential information about yourself which could reveal you as a source of that information. To reduce this risk, all personal information will be removed from your responses.

HOW WILL MY CONFIDENTIALITY BE PROTECTED?

For the purposes of this research study, your comments will be confidential. The information you share may be published in future scientific journals, but this information will be a part of a larger study without any personal information. Every effort will be made by the researcher to preserve your confidentiality including the following:

- I will assign you a code name and number that will be used on all research notes and documents. All personal identifying information will be removed from your responses. No one will be able to know which are your interview responses.
- I will keep all my notes, interview transcriptions, and any other identifying information in a locked file cabinet and on a password protected computer in my personal possession.

ARE THERE ANY BENEFITS?

During the interview you will be given an opportunity to learn about this research that may be useful to you. You will also have an opportunity to contribute to scientific research affecting your local area. This interview gives you a confidential voice to express your views about and experiences with red wolves.

WHOM SHOULD I CONTACT IF I HAVE ANY QUESTIONS?

If you have questions about the study, you may contact Suzanne Agan, at ___________If you have questions about your rights as a research participant, you may contact _________at the Institutional Review Board of Antioch University New England at _____________ You may also contact the Provost,__________.

VOLUNTARY PARTICIPATION

Your participation in this study is voluntary. It is up to you to decide whether or not to take part in this study. If you decide to take part in this study, please sign this consent form. After you sign the consent form, you are still free to withdraw at any time and without giving a reason. If you withdraw from the study before data collection is completed, your data will be returned to you or destroyed.

CONSENT

I have read and I understand the provided information and have had the opportunity to ask questions. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and without penalty. I understand that I will be given a copy of this consent form. I voluntarily agree to take part in this study.

Participant’s name (please print) ____________________ Date _________

Participant's signature ______________________________ Date __________

Investigator's signature _____________________________ Date __________

Appendix B: Interview Questions

Semi-structured Interview Questions for Landowners / Red Wolf Attitudes

1. (If interviewee is a hunter) Tell me your favorite hunting story.
    a. If they are not a hunter, their favorite outdoor experience.
2. If you own hunting land, who all hunts on your land? Just you, you and local friends, local & nonlocal hunters you don't know, people from outside the NENC area?
    a. If you talk to any of them about red wolves, what do you talk about?
3. What is your experience with red wolves?
    a. What is your primary source of information about red wolves?
    b. If you have heard red wolves, what was the context and what do you recall, if anything, that it made you think or feel?
    c. Under what conditions do you think others might confuse a coyote for a red wolf?
    d. Have you ever seen a red wolf? How confident are you in your ID of this particular species?
4. How would you describe your general attitude toward wolves?
5. What do you think about red wolves being here on the Albemarle Peninsula?
    a. How do you feel about the Service's management actions to protect red wolves? Are there certain actions/policy's you agree or disagree with? If so, which ones and why? What would ideal management of red wolves look like to you?
6. How do you think your friends on the Albemarle Peninsula view red wolves?
7. How do you think other people (not close to you) view red wolves?
8. It's currently against the law for a private citizen to kill a red wolf except in defense of life. Are there any situations you might try to kill a wolf anyway?
9. Where do you believe red wolves are most at risk of being killed? (*Use NENC map for participant to point out risk area's*) What makes you think so?
10. Would you kill a red wolf if it were illegal? Why or why not? (If they answer in the positive, what would stop them from doing so? Legal enforcement?
11. Would you kill a red wolf if it were legal? Why or why not?
12. How do you feel about the USFWS and why? What about their presence here on the Albemarle Peninsula?
13. How would you describe yourself politically?
14. What else comes to mind when thinking about red wolves that you think I should know that I haven't asked about?
    a. What should I ask other's I interview?
    b. What questions would you recommend I ask on my survey?
    c. Finally, if I were to interview a poacher, what do you believe I should ask them?
15. Demographic Information
    a. Gender
    b. Year born
    c. County of residence
    d. Zipcode
    e. Amount of land owned
    f. What is land used for

Semi-structured Interview Questions for Poachers

1. Tell me your favorite hunting story, or your favorite outdoor experience.
2. Type of game do you hunt, if any?
3. What is your experience with red wolves?
    a. What is your primary source of information about red wolves?
    b. If you have heard red wolves, what was the context and what do you recall, if anything, that it made you think or feel?
    c. Under what conditions do you think others might confuse a coyote for a red wolf?
    d. How often do you see red wolves? How confident are you in your ID of this particular species?
4. How would you describe your general attitude toward wolves?
5. What do you think about red wolves being here on the Albemarle Peninsula?
    a. How do you feel about the Service's management actions to protect red wolves? Are there certain actions/policy's you agree or disagree with? If so, which ones and why? What would ideal management of red wolves look like to you?
6. Describe your interactions with USFWS or NCDNR if any.
7. How do you think your friends on the Albemarle Peninsula view red wolves?
8. How do you think other people (not close to you) view red wolves?
9. Where do you believe red wolves are most at risk of being killed? (*Use NENC map for participant to point out risk area's*) What makes you think so?
10. Describe the events leading up to the illegal killing of a red wolf.
11. It's currently against the law for a private citizen to kill a red wolf except in defense of life. Would you illegally kill a red wolf again? Under what circumstances?
12. What would stop you from killing a red wolf?
13. What more do you believe can be done to protect red wolves?
14. How would you describe yourself politically?
15. What else comes to mind when thinking about red wolves that you think I should know that I haven't asked about?
    a. What should I ask other's I interview?
    b. What questions would you recommend I ask on my survey?
16. Do you know of anyone else who has illegally killed a red wolf that would be willing to speak with me anonymously?
17. Demographic Information
    a. Gender
    b. Year born
    c. County of residence
    d. Zipcode
    e. Amount of land owned
    f. What is land used for

Appendix C: Survey instrument

The Human Dimensions and Spatial Ecology of Poaching and Implications for Red Wolf Survival

Suzanne Agan

Survey Instrument

Internet survey.
** Most answer choices are randomized. Likert scale question is reversed randomly.

TITLE OF STUDY
Red Wolf Survey

PRINCIPAL INVESTIGATOR
Suzanne Agan
Antioch University New England
Environmental Studies
40 Avon St, Keene, NH 03431

DESCRIPTION OF THE RESEARCH

You are invited to participate in a research study about red wolves. We are interested to know your views about red wolves in North Carolina. The purpose of the research is to learn how people experience red wolves on the Albemarle Peninsula. It is my hope that this research can help inform policy makers and wildlife and conservation managers' work with red wolves.

WHAT WILL MY PARTICIPATION INVOLVE?

If you decide to participate in this research you will complete a brief internet survey which will take approximately 7 minutes to complete. This survey is specifically for people who live or own land in the following NC counties: Dare, Hyde, Tyrrell, Washington, Beaufort, Pamlico, Martin, Craven, and Pitt.

WHOM SHOULD I CONTACT IF I HAVE ANY QUESTIONS?

If you have questions about the study, you may contact Suzanne Agan, at _________or at__________. If you have questions about your rights as a research participant, you may contact ___________at the Institutional Review Board of Antioch University New England at _______(check that address).

16. To what extent would you include yourself with each of the following groups?

	Not at all	Slightly	Moderately	Strongly
a. Wildlife advocate				
b. Animal welfare advocate				
c. Hunter				
d. Conservation advocate				

e. Gun rights advocate
f. Environmental advocate
g. Farmer (crops)
h. Rancher (animals)
i. Property rights advocate

17. Which of the following best describes your status on the Albemarle Peninsula? (choose one)
    a. My family or I own land and live on the AP
    b. My family or I own land on the AP but live somewhere else
    c. My family or I rent on the AP
    d. None of the above

18. Q28 Which of the following describes how you use land on the AP (check all that apply)?
    a. Residence
    b. Agriculture
    c. Hunt
    d. Timber
    e. Wildlife habitat
    f. Rent/ air bnb
    g. Other (please specify) _________________________
    h. I don't own land on the AP

19. In what county do you own or rent land? (drop down list, conditional on #2)

20. How much land do you own on the AP (conditional on #2)?
    a. Less than 1 acre
    b. 1 – 10 acres
    c. 11-99 acres
    d. 100-999 acres
    e. More than 1000 acres

21. If you hunt on the AP, what species do you hunt (check all that apply)?
    a. Deer
    b. Waterfowl
    c. Coyote
    d. Bear
    e. Turkey
    f. Quail
    g. Rabbit
    h. Fox
    i. Other (please specify)____________________________
    j. I don't hunt

22. Q8 How would you describe your general attitude toward red wolves?
    a. Strongly dislike
    b. Dislike

   c. Slightly dislike
   d. Neutral
   e. Slightly like
   f. Like
   g. Strongly like
   h. Don't know

23. Q9 – Optional. Please describe in more detail your attitude toward red wolves

24. Q10 Which of the following experiences have you had with red wolves (check all that apply)?
    a. No experience
    b. Seen a red wolf in the wild
    c. Heard a red wolf in the wild
    d. Discussed red wolves with USFWS personnel
    e. Read or heard about red wolves in the news
    f. Attended red wolf informational meeting
    g. Seen an educational display for red wolves
    h. Visited a red wolf howling event at Alligator River National Wildlife Refuge
    i. Conducted your own research on red wolves through internet searches, reading books, watching documentaries or other media.
    j. Other________________

25. Q11 It's currently against the law for a private citizen to kill a red wolf except in defense of life (human, livestock, or pets). Are there any other situations you might try to kill a red wolf anyway?
    a. Any wolf I encounter on my own
    b. The wolf did not run away from me when I was on foot
    c. The wolf did not run away from my vehicle
    d. The wolf was on my property
    e. The wolf came too close to my home
    f. The wolf approached my pet or farm animals
    g. I would not kill a red wolf
    h. Other ________________________

26. Q26 Where do you believe red wolves are most at risk of being killed? (*Use NENC map for participant to point out risk area's*)
    a. Q31 Why do you believe this is a high risk area for red wolves?__________

27. Please state your level of support for conserving red wolves.
    a. Support
    b. Neutral
    c. Oppose
    d. I don't know enough

28. Optional, please describe in more detail your level of support for conserving red wolves.

29. What would you do if you saw a red wolf on your property?
    a. I would try to protect it
    b. I would watch it
    c. I don't know
    d. I would call the authorities
    e. I would try to kill it
    f. I would try to scare it away
    g. I would ignore it
    h. Other – please list____

30. "The US Fish and Wildlife Service proposes that, "wolves outside of the new (non-essential experimental population, NEP) management area would remain part of the NEP but take of these animals on non-federal lands would be allowed."
    What is your attitude to this proposal?
    a. Like
    b. Neutral
    c. Dislike
    d. Don't know enough to decide

31. Optional, please describe in more detail your attitude to the above proposal.

32. Please state your attitude towards the US Fish and Wildlife Service.
    a. Trust
    b. Neutral
    c. Mistrust
    d. Don't know enough
    e. Briefly explain________________

33. Optional, briefly describe in more detail your attitude toward the US Fish and Wildlife Service.

34. 
    Photo courtesy of Life and Science Museum, Durham NC
    What are the first thoughts that come to mind when seeing this image of a red wolf (only 1 image will randomly appear per survey)?

35. What is your gender?
    a. Male
    b. Female

c. Prefer not to answer

36. Q22 In what year were you born? (must enter a 4 digit number)

37. Q23 What is your zipcode?

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Suzanne,

I received your contact us form regarding red wolf photos for your PhD dissertation. You are welcome to use any of the photos that are on our Museum social media pages, we ask that you credit the Museum of Life and Science. I am also attaching one of our staff favorites.

We wish you good luck!

Best,
[redacted]

[redacted] | Digital Marketing Manager
[redacted]
(she/her/hers)
lifeandscience.org

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