Re-introduction and recovery of the red wolf in the southeastern USA.

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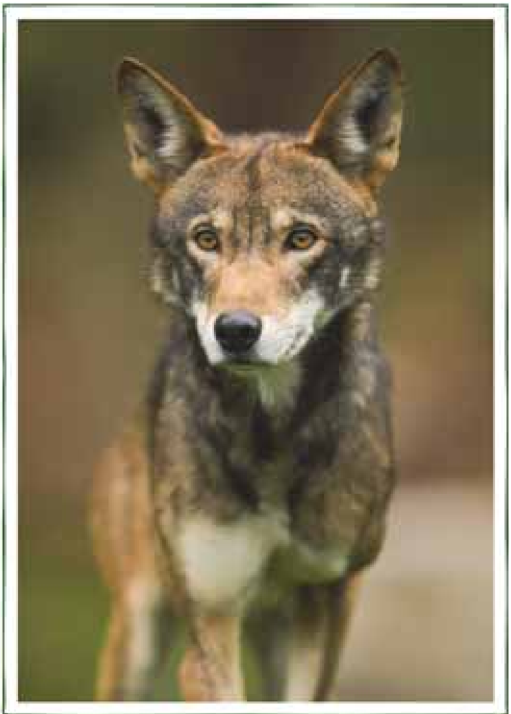
Introduction

The red wolf (*Canis rufus*) is one of the Earth's most imperiled canids. Once occurring throughout the southeastern USA, red wolves were decimated by predator-control programs and habitat degradation. Remnant populations of red wolves were further threatened by hybridization with expanding coyote (*C. latrans* var.) populations. To protect the red wolf from extinction, the U.S. Fish and Wildlife Service (USFWS) extirpated the red wolf in the wild and established an *ex situ* breeding program with plans to restore the species to a portion of its former range. Only 14 individuals would reproduce to become the founding ancestors of all red wolves existing today. Successful *ex situ* reproduction prompted a re-introduction of red wolves in northeastern North Carolina (NENC) in 1987. A second re-introduction was initiated in 1991 in the Great Smoky Mountains National Park, but later terminated because of disease and low pup survival. The restored population of red wolves in NENC has expanded to included 90 - 110 wolves occurring over more than 6,000 km^2. Nearly 200 red wolves are maintained in more than 40 zoos/ nature centers throughout the USA. The red wolf is federally listed as Endangered under the Endangered Species Act (ESA) and IUCN Critically Endangered D (IUCN, 2012).



Red wolf © John Froschauer/PDZA

Goals

Goals and success indicators of the Red Wolf Recovery Program are taken from the Red Wolf Recovery/Species Survival Plan (USFWS, 1990) and the Red Wolf 5-Year Status Review (USFWS, 2007).

- Goal: Achieve a series of geographically independent populations of red wolves, through re-introduction, that are numerically large enough to have the potential for allowing natural evolutionary processes to work within the species (USFWS, 1990).

Fostering of red wolves © David Rabon/USFWS

Success Indicators

- Indicator 1: Establish and maintain a series of at least three red wolf populations via restoration projects within the historic range of the species. Each population should be numerically large enough to have the potential for allowing natural evolutionary processes to work within the species. This must be paralleled by the cooperation and assistance of at least 30 captive-breeding facilities.
- Indicator 2: Preserve 80% to 90% of the genetic diversity found in the founding population (14 individuals) of red wolves for a period of 150 years or more.
- Indicator 3: Remove those threats that have the potential to bring about extinction of the red wolf. Achieving this objective will include maintaining a total wild population of at least 220 wolves and a captive population of approximately 330 wolves.
- Indicator 4: Maintain the red wolf in perpetuity through embryo banking and cryogenic preservation of sperm.

Project Summary

Feasibility: With the passage of the ESA, a red wolf recovery program was established in partnership with Point Defiance Zoo and Aquarium (WA, USA), to coordinate captive breeding efforts and determine "pure" red wolves as part of a planned extirpation of red wolves in the wild. Between 1973 and 1980, only 14 canids captured within the remaining red wolf range were determined to be pure red wolves and successfully bred in captivity. By 1980, the red wolf was extirpated in the wild. In 1984, the captive breeding program was accepted by the Association of Zoos and Aquariums for development of a Species Survival Plan (SSP), and plans for re-introduction were initiated. To assess various restoration approaches (e.g., acclimation, release, and recapture techniques), captive-born red wolves were released on an island propagation site. After public opposition at the initial re-introduction, Alligator River National Wildlife Refuge (ARNWR, NC) was chosen as the red wolf re-introduction area. Extensive analyses determined feasibility due to the absence of coyotes, the lack of livestock operations, and availability of prey species. To garner public support, traditional recreational activities, such as hunting and fishing, were allowed to continue within the re-introduction area, and the re-introduced population was designated "non-essential experimental" under Section 10(j) of the ESA.

Implementation:
Captive breeding: With very small populations, survival can be affected by genetic drift (random loss of allele frequency) and inbreeding depression. Currently, gene diversity in the captive red wolf population is approximately 89.65% of the founder population (N = 14), and there is little evidence of inbreeding depression.
Pre-release conditioning: As a strategy to propagate wild red wolf offspring for release, breeding pairs of wolves from captive breeding facilities were relocated to several island propagation sites. The wolves were released on the islands to live, hunt, breed, and raise their young in a natural, albeit space limited, environment. Their offspring, having been raised "wild," would be relocated to the mainland re-introduction site when they reached dispersal or reproductive age. The concept being that wild-raised red wolves would have learned to hunt and live as wild animals and were more likely to survive following release than captive-reared wolves. Most of these sites were discontinued due to human-wolf interactions or funding constraints. Currently, the St. Vincent National Wildlife Refuge (FL, USA) island propagation site remains operational.
Re-introduction: In 1987, after briefings to the public, state, and other federal agencies, re-introduction efforts of the red wolf began on ARNWR with the release of four captive-born, male-female wolf pairs. The captive-born wolves were housed in 225 m^2 acclimation pens prior to release. During acclimation, human contact was minimized, and feeding regimes were altered to resemble wild conditions. Prior to release, the wolves were given a health check, vaccinated, treated for parasites, weighed, and fitted with VHF radio-telemetry collars (Phillips *et al.*, 2003). To encourage the wolves to remain near the release site, and to facilitate predatory diet and habits, the wolves were provided supplemental food (generally deer carcasses) for 1 - 2 months following release.
Fostering: The insertion of captive-born wolves in a wild-born litter has been a successful tool to increase the number of wild red wolves and enhance the genetic diversity of the re-introduced population. Typically, captive-born pups are inserted into a wild litter when the recipient and donor pups are between 10 - 14 days old, and the recipient litter is small enough to accommodate the additional litter mates.
Adaptive management: The expansion of the coyote into the red wolf recovery area has resulted in interbreeding and coyote gene introgression into the wild red wolf population. To reduce hybridization, an adaptive management plan was developed that uses sterilized, hormonally-intact (via vasectomy and tubal ligation) coyotes as territorial "placeholders." The "placeholder" coyotes will not interbreed with red wolves, and they exclude other coyotes from their territory. Ultimately, the "placeholder" coyotes are replaced by red wolves either naturally (e.g. displacement) or via management actions (e.g., removal followed by insertion or natural dispersal of wolves into the territory).

Post-release monitoring:
Population estimation: Adult and juvenile red wolves are live-trapped, fitted with VHF radio-telemetry collars, and monitored several times a week from fixed-wing aircraft and ground surveys. Radio-telemetry techniques determine wolf movements, territory usage, pairings and interactions, den establishment and location, and fates of individuals. Passive integrated transponder (PIT) tags are

implanted in all pups found during the spring den search for identification when later captured and radio-collared as adults. Population estimates of wild red wolves are calculated by adding the number of actively monitored radio-collared wolves and PIT-tagged pups recorded during the spring whelping season.
Current conservation status: As of 2012, ~90 - 110 red wolves are surviving in the wild, of which 65 are regularly monitored through radio-telemetry. However, the species only exists in the wild in the one re-introduced population. The captive breeding population remains stable at ~200 red wolves.

Major difficulties faced

- *Human-caused mortality*: From September 1987 through December 2012, mortalities were documented for 364 wild red wolves in NENC. Demographic data were available for 357 red wolves, including 72 pups, 94 juveniles, and 191 adults (many of which were breeders). For the first 25 years of re-introduction, causes of death were determined for all red wolves in the NENC re-introduction area. Causes of red wolf mortalities included suspected illegal activities, involving gunshot, poisoning, and other suspected illegal take (30%); vehicle collisions (20%); health-related causes (16%); intraspecific competition (6.5%); management actions (5.0%); private trapping (3.5%); and, unknown causes (19%). Fifty-seven percent of all observed mortalities (72% of mortalities with a known cause of death) during this period were human-caused and potentially avoidable. During the past nine years (2004 - 2012), the average annual number of gunshot-caused mortalities has increased ~375% when compared to earlier years (1988-2003).
- *Disease:* Canid diseases have threatened both re-introduced and captive red wolf populations. The magnitude of risk to the red wolf species overall is partly offset by captive red wolves held in more than 40 SSP zoos and nature centers across the USA. Risk of disease is also partly offset by intensive vaccination programs for both re-introduced and captive red wolves. However, veterinary research scientists caution against the assumption that vaccinated red wolves are adequately protected against diseases. The diseases of greatest concern are canine distemper (Genus *Morbillivirus; CDV)*, canine parvovirus (Genus *Parvovirus; CPV1, CPV2)*, leptospirosis (Genus *leptospira*), hemobartonellosis (*Haemobartonella canis*), borrelliosis (Lyme disease, *Borrelia sp.*), demodectic mange (*Demodex canis* mites), sarcoptic mange (*Sarcoptes scabiei* mites), heart worm (*Dirofilaria immitis*), and rabies (Genus *Lyssavirus, rabies virus*). The impacts of CPV2 parvovirus on pup survival in the Great Smoky Mountains National Park re-introduction area eventually contributed to the termination of that project. Fortunately, to date, none of these diseases have occurred at sufficiently high levels to cause an epidemic. However, mange (N = 17) and heartworm (N = 7) have been confirmed as repeated sources of red wolf mortality in the re-introduced population. New threats also are becoming more prevalent in local domestic dogs, including the Lyme disease-causing bacteria *Borrelia burgdoferi*.
- *Interbreeding with coyotes:* The recovery and restoration of red wolves requires the careful management of coyotes and occasionally red wolf-coyote hybrids in the red wolf re-introduction area. The non-native coyotes spread across the eastern USA, reaching NENC in the early to 1990s. It soon was

recognized that interbreeding between red wolves and coyotes would produce hybrid offspring resulting in coyote gene introgression into the wild red wolf population, and that this introgression would threaten the restoration of red wolves. An adaptive management plan (Rabon *et al.*, 2013) was developed to reduce interbreeding and introgression while simultaneously building the red wolf population. The adaptive management plan effectively uses techniques to capture and sterilize hormonally intact coyotes via vasectomy or tubal ligation, then releases the sterile canid at its place of capture to act as a territorial "placeholder" until the animal is replaced by wild red wolves. Sterile coyotes are not capable of breeding with other coyotes, effectively limiting the growth of the coyote population, nor are they capable of interbreeding with wild red wolves, limiting hybridization events. In addition, the sterile canid will exclude other coyotes from its territory. Ultimately, the placeholder coyotes are replaced by the larger red wolves either naturally by displacing the coyote or via management actions (e.g., removal of the coyote followed by insertion of wild or translocated wolves).

Typical red wolf habitat © Melissa McGaw

- *Climate change and stochastic events:* Natural weather events and global climate change will play growing roles in long-term survival and recovery of red wolves, especially in the re-introduced red wolf population. The re-introduced wild red wolf population in NENC, as well as many of the captive SSP facilities, is subject to the adverse effects of annual tropical storm activity. Hurricane Isabel (2003) resulted in the deaths of two captive red wolves, and Hurricane Sandy (2012) resulted in the death of one captive red wolf. Although there has been no noticeable long-term impacts observed on the red wolves in the re-introduced population, the red wolf restoration area and associated habitats and prey species are vulnerable to sea level rise and flooding related to climate change and tropical events. Additional long-term changes in habitat availability, prey abundance, and other ecological or landscape factors will occur with climate change. Thus, long-term assessment and planning are needed that consider the current re-introduced and future populations in the context of tropical storm activity, global climate change, and resulting changes in the North American landscape over time.

Major lessons learned

- *Partnerships and cooperation are essential for success:* Cooperation and creative partnerships are essential to the success of any re-introduction program. The successful captive red wolf breeding program is a result of the cooperation of Point Defiance Zoo and Aquarium, the development of an Association of Zoos and Aquariums SSP program, and the participation of numerous SSP-affiliated zoos and nature centers. Consequently, captive breeding has become a foundation of the success of the red wolf recovery program. Researchers and other science-based partners have provided data and information necessary to make management decisions that support restoration actions to ensure sound conservation approaches to recovering the red wolf. Re-introduction requires cooperation and partnerships among many diverse groups, particularly among local, regional, and state-wide governments, private landowners and land managers, researchers, and special-use groups and organizations.
- *Disease prevention and surveillance are prudent:* Because canid diseases can spread quickly, they can cause serious setbacks in red wolf recovery, and remain serious threats to all red wolf populations. As evidenced by the termination of the Great Smoky Mountains National Park re-introduction project due to poor pup survival and parvovirus, additional precautions are needed to proactively address potential disease outbreaks in any re-introduced red wolf population. The establishment of at least two more re-introduction sites within red wolf historic range could partly alleviate disease risk. The import of existing and new strains of canid diseases carried into a re-introduced red wolf population also is a concern. Domestic hunting dogs and imported coyotes from elsewhere in USA are two potential outside sources of disease. A red wolf disease prevention and surveillance program has been recommended to ensure long-term survival for any red wolf re-introduced population.
- *Early development of regulatory mechanism is critical:* The red wolf remains federally listed as Endangered throughout its historic range. However, the red wolf was declared extinct in the wild in 1980 when the last known remaining red wolves were brought into captivity. Therefore, red wolves in captivity are listed Endangered, whereas re-introduced red wolves are designated as a nonessential experimental population under 10(j) of the ESA.
  - The nonessential experimental status for the

Red wolf with radio-collar © Ryan Nordsven/USFWS re-introduced population of the red wolf is a helpful mechanism which allows managers to work cooperatively with partners to enhance red wolf recovery and resolve problems. The nonessential experimental status also allows flexibility for landowners and managers, and other citizens by allowing exceptions to the prohibitions of take under the ESA when a red wolf constitutes a demonstrable threat to human safety or livestock, provided it has not been possible to eliminate such threat by live capture and relocation of the wolf. Such flexibility allows less regulation while addressing needs in human safety and property. However, there is room for improvement to ensure that federal listing status of the red wolf is mirrored by state listing status such that it promotes red wolf conservation and synergy in red wolf recovery.

- *Sterile coyote placeholders can deter hybridization:* During the initial site selection process for the red wolf re-introduction program, the NENC red wolf recovery area was considered uninhabited by coyotes. However, coyotes have expanded their historical range eastward; individuals were observed in the recovery area beginning in the early-1990s. As a result, an adaptive management plan was needed to attempt to eliminate the threat of hybridization. Research has demonstrated that sterilized coyotes remain territorial and continue to defend space. It is this concept of holding space that is being applied to manage hybridization by providing managers time, information, and a higher degree of control over the recovery landscape, while simultaneously providing reproductive advantage to the red wolf. Ultimately, sterilization is a method that allows territorial space to be held until that animal can be replaced naturally or by management actions. Sterile or "placeholder" coyotes are then naturally replaced when the larger red wolves displace or kill the coyote. Occasionally, a coyote may be removed from an area when there is an opportunity to insert a wild or translocated red wolf into that territory or if there is a red wolf dispersing into that area.

Success of project

Highly Successful	**Successful**	Partially Successful	Failure
	√		

Reason(s) for success/failure:

- *Socio-politics:* Socio-political views of the red wolf, and wolves in general, have a long history. The wolf was maligned in folktales, fables, and fairy tales, and persecuted in reality. Euro-American colonists, acting on prejudice, established a bounty on the wolf that spread like an epidemic with the growing nation. With the expansion and increasing number of pastoralists, the wolf was seen as much as an ecological competitor that threatened livestock and livelihoods as it was a diabolical and malevolent beast. The widespread use of a bounty extirpated the wolf in many regions. By the early-1900s, government-operated predator control programs had the task of systematically exterminating the wolf, further driving the red wolf to near extinction. Eventually, the wolf was romanticized in literature, reversing the public's sentiment, or at least the government's role in their eradication. By the later part of the 20th century the public's attitude had swayed enough to support legislation to protect the species. Decades of successful restoration activities and the unfulfilled prophecies of the wolf's devastating impact on the local wildlife or livelihoods has assisted in furthering the positive change in attitudes. But localized animosity toward the red wolf still exists in landowners and land managers that see the wolf as an ecological competitor despite the increasing recognition of red wolves as ecologically important. The red wolf continues to be persecuted, requiring additional management interactions to maintain the red wolf population.

- *Adaptive management techniques:* Adaptive management techniques have shown that sterilization is a method that allows territorial space to be held until that animal can be replaced naturally or by additional management actions. Sterile or "placeholder" coyotes are then naturally replaced when the larger red wolves displace or kill the coyote. Ongoing analyses suggest that red wolves always win over coyotes in the battle of territorial disputes, whether management actions were taken or not to remove a coyote. Preliminary data analyses show no instances of a coyote successfully defending a territory against a red wolf. Space is limited in the re-introduction area. Ideally, within the re-introduced red wolf population in NENC, that space is initially best occupied by breeding pairs of red wolves, non-breeding mixed (red wolf/coyote) pairs, and non-breeding coyote pairs. By sterilizing coyotes, introgression of non-wolf genes will be controlled and territories will be unavailable for colonization by breeding coyote pairs or breeding red wolf-coyote pairs. In addition to the ~65+ radio-collared red wolves, there are also ~60+ sterilized, radio-collared coyotes regularly monitored. As the red wolf population grows, having space available for dispersing red wolves will become increasingly important, and this space will be provided through natural interspecific competition and/or management actions.
- *Persistence and patience:* Coyote expansion and the threat of hybridization and genetic swamping of the small remnant red wolf populations ultimately lead to an abandonment of the attempt to preserve the red wolf in the wild in the late-1960s. When planned extirpation of the wild red wolves and the establishment of a captive breeding program were determined to be the only solutions, then the captive breeding process was marred by the availability of pure red wolves. Only 14 red wolves were determined "pure" and verified through a breeding certification program, becoming the founding population of all red wolves in existence today. Captive breeding also was hampered by a slow start in the production of viable offspring. It was not until 1977 when the first litter of red wolves was born in captivity that the real steps in red wolf recovery were made. The red wolf captive breeding program has grown and developed since 1973, ensuring and maintaining the genetic diversity of the species. More than 40 zoos and nature centers that breed red wolves have committed substantial resources, without compensation, to the captive breeding effort. Re-introduction of captive-born red wolves into the wild began in 1987 and continued until 1994. However, red wolves were born in the wild every year since the first wild-born litter in 1988. Fortunately, program partners remain committed to re-introduction, and new partners are joining the recovery effort.

- *Continued research and monitoring:* An adaptive approach to recovery program management has allowed research to address ongoing and emerging issues facing the red wolf recovery program. Several identified research needs include demographic analysis of the effects of gunshot mortality on red wolf population dynamics; development of a two-species model to show how the presence and interactions with coyotes impact habitat suitability indices and red wolf carrying capacity; monitoring how pre-release conditioning can improve survival and establishment of a territory; careful genetic management of the captive population and the development of artificial insemination and cryopreservation techniques; and investigating how pup fostering can increase numbers and genetic diversity in the re-introduced population.

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