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From the Field: Implementing recovery of the red wolf—integrating research scientists and managers

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Abstract The United States Fish and Wildlife Service (USFWS) developed guidelines for the composition and role of endangered species recovery implementation teams, but few teams have been established and their success has not been evaluated. Using the recovery program of the red wolf (*Canis rufus*) as a model, we describe the genesis, function, and success of the Red Wolf Recovery Implementation Team (RWRIT) in helping guide the establishment of a viable red wolf population in eastern North Carolina. In operation since 1999, the RWRIT meets bi-annually to review USFWS progress and provide recommendations aimed at maximizing success of species recovery. The team is comprised of 8 research scientists from disciplines including population genetics, canid ecology, population ecology, veterinary medicine, and captive management. Representation from each of these disciplines is deemed necessary for proper evaluation of recovery progress and assessment of future needs. Meeting attendance by the USFWS field management team ensures both proper reporting of past progress and future implementation of management recommendations. Over time, RWRIT members have assumed specific assignments for data analyses, further contributing to the recovery effort. Through the combined efforts of the USFWS field team and the RWRIT, the threat of introgression of coyote (*Canis latrans*) genes into the red wolf population has been substantially curtailed within the recovery area, and red wolf numbers and range have increased. The RWRIT serves as an example of a recovery implementation team that is successfully incorporating the principles of adaptive management and whose template could be adapted to other endangered species.

Key words adaptive management, *Canis rufus*, endangered species, implementation, recovery, red wolf

Recovery of any endangered species is influenced by a range of political, economic, social, as well as biological issues (Tear et al. 1993, Scott et al. 1995, Lundquist et al. 2002). Reconciling disparate concerns and perspectives into a cohesive program requires planning and decision-making processes that consider conflicting interests of various stakeholders. However, for a recovery program to succeed, it is equally critical that professionals tasked with the responsibility for managing endangered species be able to move forward with timely decisions based on practical management needs and scientific knowledge (Westrum 1994). The United States Fish and Wildlife Service (USFWS) red wolf (*Canis rufus*) recovery program is an example of a program faced with complex issues, where man-

agement successes have been strengthened and accelerated by integrating active adaptive management with careful and timely scientific inquiry. This paper describes how this integration is being achieved via a designated "recovery implementation team."

The red wolf is an endangered species that once roamed an extensive range including the southeastern United States, and possibly the entire woodlands of eastern North America (Wilson et al. 2000, Nowak 2002, Grewal et al. 2004). Although listed as endangered in 1967 (USFWS, 1967), population decline and apparent hybridization with coyotes (*Canis latrans*) were recognized in the early 1960s (McCarley 1962, McCarley and Carley 1979). The remaining red wolves were removed from the wild in the mid- to late 1970s with the goals of establishing a captive breeding program and eventually restoring captive-bred animals to portions of their historical range (U.S. Fish and Wildlife Service [USFWS] 1989). In 1987 the first red wolves were released in easternmost North Carolina (Figure 1) with the plan to establish a viable population (Parker 1987). The reintroduction efforts faced a myriad of social, political, and biological issues as the Red Wolf Recovery Plan (USFWS 1989) was implemented (Henry and Lucash 2000, Phillips et al. 2003).

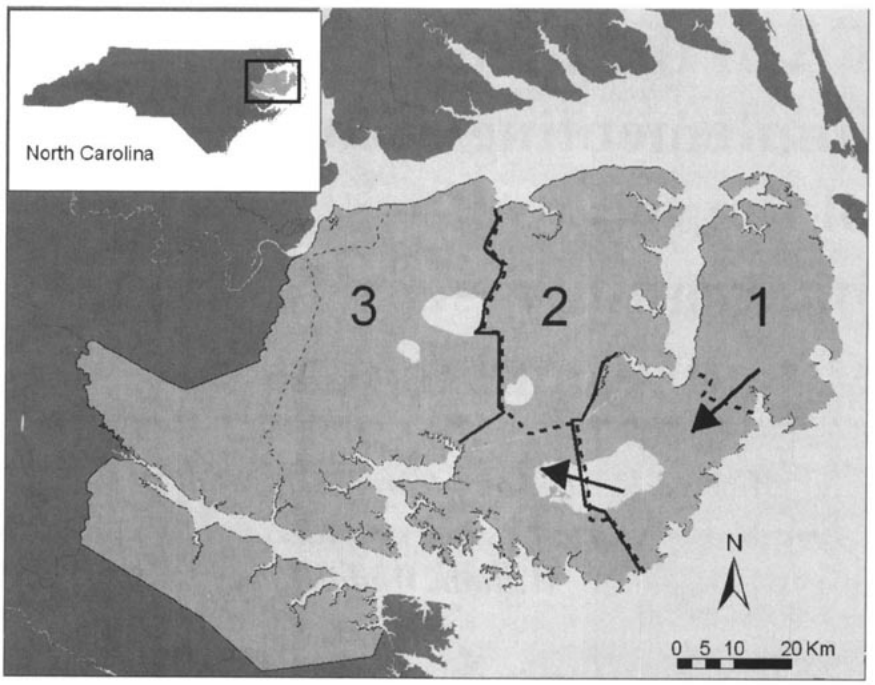

Figure 1. Changes in management zone boundaries within the Red Wolf Recovery Area of eastern North Carolina, as made in accordance with Red Wolf Adaptive Management Plans. The boundaries of the original management Zones 1, 2, and 3 (dashed lines) were first established in April 2000. In March 2002, as red wolf recovery proceeded, boundaries in the southern parts of the zones were moved west (solid lines); part of Zone 2 became Zone 1, while part of Zone 3 became Zone 2 (arrows). In August 2003 some management aspects of canids (i.e., sterilization vs. euthanasia) captured in the eastern half of Zone 3 (thin dotted line) began to follow guidelines applied to Zone 2.

Although the reintroduction area was initially considered uninhabited by coyotes, by the mid-1990s it was apparent coyotes had infiltrated the area and hybridization with red wolves was recurring (Phillips et al. 2003). Due primarily to the renewed hybrid threat and termination of the reintroduction of red wolves into Great Smoky Mountains National Park (Henry 1998), the USFWS decided it needed to re-evaluate its red wolf recovery effort in light of what had been learned over the previous decade. A key step in this review process involved a Population and Habitat Viability Assessment (PHVA) organized by the USFWS in 1999 and facilitated by the Conservation Breeding Specialists Group of the World Conservation Union, Species Survival Commission (IUCN SSC) (Kelly et al. 1999). The diverse assemblage of attendees, representing a variety of expertise and interests, agreed that introgression of coyote genes into the red wolf population was the principal threat to recovery success (Kelly et al. 1999). The group also recognized this issue required urgent attention before hybridization became so pervasive as to virtually ensure the genetic swamping of the only extant free-ranging population of red wolves. However, 2 views of how to address the hybrid threat emerged from the PHVA; one believed research was integral to addressing the problem, and the other expressed concern that research efforts would distract from the primary goal of maintaining the only free-ranging population of red wolves in the world. A consensus agreement was reached on this debate and resulted in an overarch-

ing workshop statement, including:

> "...our primary recovery focus must be protecting and promoting the growth of a self-sustaining, non-hybridizing population of red wolves in the wild and sustaining an active captive component. Actions to be taken will use an adaptive management approach that will not compromise the ability to achieve this goal." (USFWS 1999:52)

This level of agreement among the diverse participants of the PHVA set the stage for designing an adaptive management plan (*cf.* Lancia et al. 1996) that would reduce the threat of wolf-coyote hybridization. This plan (Kelly 2000) diverged from conventional endangered species management because it involved an incremental process tailored to modify field protocols according to past success in eliminating the threat of hybridization. Specifically, it required the release area to be segregated into several defined management zones, each managed to provide an integrated optimization of risk reduction within the resource limitations available to the project (Figure 1). As nonwolf canids were removed from given zones and replaced with red wolves, management options could be adapted by modifying zone boundaries or adjusting specific management protocols.

Adoption of this plan, requiring frequent re-evaluation of data and attendant management adjustments, spawned close interactions between USFWS field biologists and scientists with backgrounds relevant to the work being undertaken. A Red Wolf Recovery Implementation Team (RWRIT) was formed to advise USFWS as they implemented the adaptive management plan; this team was created pursuant to Section 4(f)(2) of the amended Endangered Species Act (ESA), which authorizes the Secretary of the Interior to procure the services of appropriate public and private agencies, institutions, and other qualified persons to help implement endangered species recovery plans. Other USFWS-designated species-specific implementation teams, as opposed to planning teams, have been formed (e.g., black-footed ferret [*Mustela nigripes*], northern right whale [*Eubalaena glacialis*], Okaloosa darter [*Etheostoma okaloosae*], and southern sea otter [*Enhydra lutris*]; USFWS files), but they are rare and no formal description of one's workings or success has yet been documented.

Recovery implementation team composition

Selection of the RWRIT scientists and their leadership was important to the success of implementing and evaluating the adaptive management plan. The PHVA helped the USFWS identify individuals with the combined expertise and personality considered important in a functional RWRIT. The PHVA also provided insight to the breadth of expertise needed over the long term. This expertise included such diverse fields as systematics, genetics, population modeling, health management, and canid biology, behavior, ecology, and management. Social scientists were not required in this case because those issues were, and continue to be, successfully dealt with by the USFWS field management team in conjunction with non-governmental organizations (Henry and Lucash 2000). Direct experience with the red wolf was not a requisite criterion for RWRIT membership. In fact, due to the long and controversial scientific history of the red wolf, some team members were sought for their naiveté of red wolves to minimize preconceived notions regarding the problems the adaptive management plan addressed. Thus, a mixture of experienced and young research scientists with strong records of scientific productivity and interpersonal skills was selected. Each member of the RWRIT had to be willing to use a data-driven approach to decision-making while remaining open to challenges of interpretation. Each member also had to be willing to accept group decisions as well as devote considerable personal time toward solving issues associated with the red wolf program.

The RWRIT needed to be large enough to provide the scientific diversity needed to assess the broad range of critical issues, but small enough to support close working relationships among members and result in productive meetings (Clark and Westrum 1989). A basic philosophy was that if the RWRIT needed expertise from individuals or disciplines outside the RWRIT to address specific issues, guest scientists would be invited to participate in the appropriate meetings. Initially, a goal of 8 members and 4 alternates was considered. Interactions of the group and reliability of participation in early meetings were used to identify the core members of the RWRIT. Since then, the size and composition of the RWRIT (8 members, no alternates) has worked well, sustaining effective decision-making with absences at meetings being rare. The leader of

the RWRIT needed to moderate meetings efficiently while allowing for creative interactions among RWRIT members. To ensure this, a senior scientist at a local university was selected due to his demonstrated scientific and leadership skills.

Experienced and stable field team

The USFWS field team involved in the day-to-day operation and management of the red wolf recovery program was key to the success of the RWRIT. The field team attended all RWRIT meetings as nonvoting members and provided the necessary data and expertise for the meetings to progress effectively. This distinction between the teams initially caused some anxiety, but this subsided once roles had been fully elucidated. The field team is remarkably stable and has worked cohesively on the red wolf project for many years (Phillips et al. 2003). Scientists of the RWRIT recognize the field team as the most experienced red wolf biologists and essential for successful functioning of the RWRIT itself. In turn, the field team's willingness to listen to and implement recommendations made by the RWRIT has been a critical factor in the success of the program. Open communications between the 2 teams keeps RWRIT scientists aware of the implementation of recommendations and fosters respect for the dedication of the field team.

Getting started

The first meeting of the RWRIT was important in establishing the tenor of group interactions and future functioning. Subsequent meetings would focus on examining data related to specific questions within an established agenda, but the first meeting focused on developing operating procedures for decisions as well as the types of data and data formats the team preferred for review and evaluation. This was a step that helped acquaint members of the team and recognize proper working protocols. It also ensured that all members of the team had a common understanding of the Red Wolf Adaptive Management Plan (RWAMP).

The charge of the RWRIT was established a priori by the Team Leader of the Red Wolf Recovery Program (i.e., "Red Wolf Program Leader"). This task was defined specifically as reviewing progress on the RWAMP and recommending changes to the plan based on data provided by the USFWS. As the team gained experience, this charge evolved to include recommendations for data relevant to answering specific questions important to the field team in the day-to-day management of the wild red wolf population. The 2 charges were closely related, frequently blended, seldom distinct, fundamental to the Adaptive Management Paradigm (Walters 1986), and are the responsibilities that drive efforts of RWRIT members. From the beginning, per the ESA, RWRIT recommendations were strictly advisory, with decisions for implementation being at the discretion of the USFWS.

Ground rules established in the first meeting have rarely been adjusted. Some established the mechanics of operations. For example, it was decided a minimum of 6 RWRIT members would be required as a quorum for a functional meeting. Failure to achieve quorum would trigger an evaluation by the RWRIT Leader and the Red Wolf Program Leader to assess whether the RWRIT remained an appropriate mechanism. To date this has not been necessary due to continued strong and enthusiastic attendance.

Other rules provided guidance for RWRIT interactions. To reduce stifling potentially meritorious but perhaps unconventional ideas, the team adopted a basic rule indicating that speakers must present alternative solutions when challenging or negating a proposed idea or approach. Ideas would be withdrawn from consideration only after careful efforts to refine them failed to produce workable solutions. To the fullest extent possible, data would be used to support all positions.

Other procedural mechanisms established in the first meeting have had a beneficial effect on RWRIT operations. For example, tentative dates, times, and location of future meetings are established jointly early in the agenda of each meeting. In addition, the agenda of the next meeting is established near the completion of the current session, which probably produces a more dynamic agenda than a call just before the meeting. Opportunities to add agenda items at any time remain, but the draft of the agenda appears in the final minutes; serving as a reminder for participants as they prepare for the coming meeting.

An important activity reserved for the end of each meeting is an exercise in prioritizing "action items", which are further classified as either "tasks" (expected to be accomplished within the time frame of the meeting or between meetings); "projects" (longer duration activities); or "manuscripts" (the drafting of information for publication).

Individual RWRIT members are recognized as responsible for addressing each item. With many issues to consider and an active agenda, many more action items are identified than can typically be accomplished with the resources available. The action items established throughout the meeting and recognized as "projects" are assembled in a descriptive list and as a final exercise, each member of the RWRIT assigns a priority level to each item and the mean rating is computed. This rating is offered to the Red Wolf Program Leader as a recommendation for activities to pursue or fund. At the first meeting, a pattern was established where RWRIT members worked to identify key management questions and to focus scientific inquiry in areas of need with constant reference to the adaptive management plan. Assets are identified and resource limitations discussed so recommendations have a reasonable likelihood of implementation. Short proposals outlining the objective of projects and the team member(s) involved in the work are distributed to the RWRIT via the team's webpage. The webpage also includes team member contact information, minutes of meetings (see below), data sets, reports, press releases, publications, project descriptions, manuscripts in progress, and upcoming meeting agendas and related materials such as reports and summaries.

Since 2000 the RWRIT has met bi-annually, which is sufficient to respond in a timely manner to questions from the field and to strengthen collegial bonds among members. This schedule also allows sufficient time for the field team to implement recommendations and to document their progress and for RWRIT members to work independently on action items. Other factors affecting meeting schedules include a need to make recommendations ahead of budget deadlines and to accommodate schedules of the individual RWRIT members and the field team. The current pattern of meetings includes 1 meeting in March prior to the denning season and a second in October prior to intensive trapping efforts.

Staying flexible

Any group with dynamic tasks needs a mechanism for adjusting the nature of the group as it matures and as tasks change (Clark and Reading 1994). The concept of alternate members soon was abandoned because of the strong attendance by RWRIT members and because it reduced inefficiencies associated with updating new attendees. The ability to invite experts in areas not represented on the RWRIT provides a mechanism to maintain flexibility and adaptability. Periodic review of expertise needed for specific tasks and projects of the RWRIT keeps the issue of change before the team. In addition, there exists ample opportunity to discuss candidly both the pros and cons of the teams' efforts, either formally at the end of each meeting or informally during meals or after hours. The RWRIT Leader needs to recognize dissenting views and address contentious issues promptly and effectively. The fact that for most meetings the entire RWRIT was communally housed in rented accommodations further ensured the establishment of favorable personal relationships benefiting RWRIT interactions and discussion.

Complete minutes of RWRIT deliberations provide documentation of the team's discussions and recommendations. An iterative process of editing minutes is used by the RWRIT, ensuring important information developed at each meeting is recorded accurately and in language deemed appropriate by the participants. Notes are converted into a draft each evening and individualized, and printed copies are distributed to attendees the following morning for editing. All drafts are synthesized into the penultimate draft for further comment, which is followed by a final draft distributed electronically shortly after completion of the meeting. The RWRIT members have a week to return any corrections, after which the final minutes are completed and distributed electronically. The deliberations of the RWRIT are considered privileged communication, and all meeting participants are asked to limit discussions of information received at the meetings to individuals within their respective research groups. This policy allows RWRIT members access to sensitive and preliminary data and provides more freedom of discussion without concerns about inappropriate disclosure. Distribution of the minutes beyond the RWRIT is at the discretion of the Red Wolf Program Leader.

How well does it work?

The test of any system is how well it functions to meet the goals and objectives of the program it serves. In the 4 years since the first formal meeting of the RWRIT, key challenges to implementing the plan developed at the PHVA have been identified and strategies have been devised to provide practi-

cal solutions and evaluate success of recovery efforts. Perhaps more importantly, all RWRIT members and the entire red wolf field team have become close colleagues who look forward to each meeting. We enjoy the frank and open exchange of ideas, the ability to quickly address both practical and theoretical problems and make changes in management practices, and the successes in the field that result from the collaboration. The details of these changes and successes are the basis of several scientific papers, some already published or in press and others currently in preparation, but a brief summary is warranted.

Prior to 1998 all canids captured in the red wolf recovery area were assumed to be wolves unless they were so small as to be considered coyotes, if they were black, or if they looked part dog. If there was some indication that a single female wolf was consorting with a coyote or dog, pups she produced were removed (A. Beyer, USFWS, personal communication). Thus, the basic challenge of rapidly and confidently identifying animals as red wolves versus hybrids or coyotes, especially young animals, was identified early as a key concern of the PHVA and the field team. The RWRIT served as catalyst for developing an enhanced and improved genomic testing protocol by expanding the ability to assess alleles at 19 loci (Miller et al. 2003). A priority placed on obtaining genomic assessments of the entire group of founders in the captive breeding program, as well for coyotes in the vicinity of the wolf release zones, greatly improved the confidence in the genomic data now available. Genetic analyses were integrated with pedigree and morphometric data to develop decision trees for all captured animals (Table 1). Extension of the DNA analysis capabilities to fecal samples increased the potential for assessing presence of red wolves, as well as undesired non-red wolves, in the field samples without the need of capturing and handling animals (Adams et al. 2003). Additional research efforts were directed at using this technology for assessing red wolf population size (J. R. Adams and L. P. Waits, University of Idaho, unpublished data).

To evaluate progress of the adaptive management plan, RWRIT scientists wanted detailed and current descriptions of animal locations, their genotypes, and canid inventory efforts in relation to geographic areas. A coordinated Geographic Information System (GIS) database system is now used at all RWRIT meetings to examine recovery progress. This is steadily approaching the goal of a real-time data view as data entry and validation challenges are addressed and data summaries are refined. These tools help identify areas where data are insufficient to define the status of canids and help develop strategies to eliminate so-called "areas of ignorance" by concentrating efforts in areas needing more attention. In addition, they have lead to improved ground telemetry efforts and more efficient use of resources and personnel.

Modeling effects of coyote genomic intrusion, using more refined data sets and newer models than available at the PHVA, provided RWRIT scien-

Table 1. Decision path for genetic results of red wolves (RW) captured in the experimental population area in northeastern North Carolina, applied in fall of 2003 (explanation of genetic result classifications given in Miller et al. 2003). Decision parameters listed in the following priority: Genetic testing; Pedigree; Morphology; Mate.

	Capture location[a]	
Decision parameter	Zone 1	Zone 2
1. Genetic test: 100% RW (pedigree 100% RW)	Release	Release
1. Genetic test: 100% RW but cannot exclude 75% RW hypothesis	Consider pedigree (go to 2)	
2. Pedigree is 100% to 87.5% RW	Release	Release
2. Pedigree is 87% to 75% RW or unknown	Consider morphology (go to 3)	
3. Morphologically "hybrid-like"	Euthanize	Sterilize
3. Morphologically "RW-like"	Consider mate (go to 4)	
4. Mate is ≥75% RW	Release	Release
4. Mate is <75% RW or uncertain	Euthanize	Sterilize 1 mate
1. Genetic Test: 75% RW or 75% RW but cannot exclude 50% RW hypothesis	Consider pedigree (go to 5)	
5. Pedigree is <75% RW	Euthanize	Sterilize
5. Pedigree is ≥75% RW or unknown	Consider morphology (go to 3)	

[a] See Figure 1.

tists new insights into impacts of genomic intrusion (e.g., Miller et al. 2003). This allowed for key insights to establishing acceptable risks defined in the decision trees. This also assisted in the making of informed recommendations for modifying approaches to the various management zones for red wolf recovery. Recently, the RWRIT initiated an effort to conduct detailed analyses of home range, spatial interactions, habitat use, and demographic attributes of all radiomonitored red wolves since 1986, with the objective of developing a population viability model to help guide future management and recovery actions. Den management techniques via implementation of early genomic sampling and use of cross-fostering of wild-caught and captive bred pups into wild litters have been developed (cf. Kitchen and Knowlton, *in press).* Methodology also has been enhanced to conduct surgical procedures to support the use of hormonally intact but sterile hybrids and coyotes to serve as sterile buffers (i.e., temporary territory placeholders that discourage establishment of new, intact nonwolves) in peripheral management zones (Figure 1).

The net result of such activities has led to an increase in the area occupied by red wolves, total number of red wolves, and number of red wolf social units, as well as a major decrease in the total area where the status of canids, in general, is unknown (B. B. Fazio, USFWS, unpublished data). Such changes in these metrics were identified in the RWAMP as key indicators of the successful management of wolf-coyote hybridization. Importantly, coyotes or hybrids have essentially been eliminated from fully half of the red wolf recovery area. To date, genetic intrusion into the red wolf population has been largely controlled, albeit through aggressive intervention.

The effective functioning of the RWRIT has ensured that issues identified at the PHVA as described in the RWAMP have been, or are being, successfully addressed by USFWS. And as should be expected, the original red wolf adaptive management plan is now revised to include 5 years of evolving adaptive management (Fazio et al. 2004). The approach taken by the RWRIT represents a good example of successful application of the Adaptive Resource Management paradigm and is likewise consistent with, and respectful of, concerns raised by the participants at the PHVA that the primary goal of conserving the only free-ranging population of red wolves not be overshadowed by the desire to conduct research. Indeed, the USFWS recently highlighted the efforts of the Red Wolf Recovery Program in a videotape on how the use of sound science is key to meeting its mission.

We believe the recent tangible success in red wolf recovery is a direct result of conducting the PHVA, crafting a RWAMP, establishing the RWRIT, and the cooperation and close interaction between the RWRIT and the USFWS field team directly tasked with red wolf recovery. Endangered species recovery should involve a strong linkage between scientific investigation under the rubric of adaptive management and the appropriate blend of social, political, and economic issues (Clark et al. 1994). In light of the mixed past success in recovering endangered species in the United States (Crouse et al. 2002, Gerber and Hatch 2002), we believe, based on the success of the RWRIT, that recovery implementation teams can serve as an effective vehicle for helping guide recovery programs and actions.

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The collaborators on this paper have a variety of academic degrees, work experiences, and publications in a wide selection of fields and disciplines and have studied species from A to Z. They include (seated, from left to right) ***Karen Beck*** (ecological epidemiologist), ***Buddy Fazio*** (fiscal conservationist), ***Todd Fuller*** (quasi-experimental theoriologist), ***Eric Gese*** (investigative carnivologist), and ***Brian Kelly*** (politico-ecologist), and (standing, left to right) ***Fred Knowlton*** (historical canidilist), ***Dennis Murray*** (taxon-free numero-ecologist), ***Michael Stoskopf*** (conservation metabonomist), ***Will Waddell*** (ex-situ zoologist), and ***Lisette Waits*** (pan-molecular faecologist).