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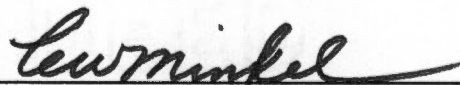


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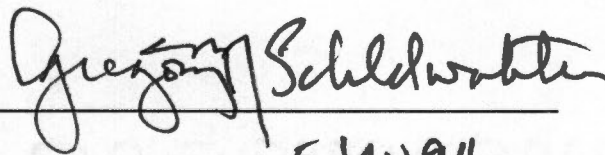
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**THE PILOT-REINTRODUCTION OF RED WOLVES
IN GREAT SMOKY MOUNTAINS NATIONAL PARK**

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Gregory T. M. Schildwachter

May, 1994

DEDICATION

This thesis is dedicated to my parents

Mr. Stephen John Schildwachter

and

Mrs. Anne Elizabeth Crawford Schildwachter

who opened the world to me, told me about Jesus Christ,

supplied me with tools, and urged me on.

ACKNOWLEDGEMENTS

The time and effort demanded by this project brought me into close scrutiny of the limits of my knowledge and abilities, challenged me to extend these quantities, and therefore impressed this experience deeply in me. Accordingly, I have become very fond of the people who shared this time with me and who assisted me in the work.

First, I thank God himself. The deeper I look into ecology, the more clearly I see his love, which is as evident there as in the gift of Christ. Second, the people who stand by me always: my parents and family, A. L. Thayer, and M. V. Mattison.

The work itself would not have been possible without my advisor, M. R. Pelton, the staffs of the U. S. Fish and Wildlife Service Red Wolf Recovery Program and of Great Smoky Mountains National Park, and my committee members, D. A. Buehler and R. W. Mee. I learned much about work and chess from C. Lucash. F. T. Van Manen provided me companionship and collaboration that was a model, a reference, and an inspiration.

Other faculty members of the University of Tennessee assisted me and took personal interest in the work. In particular, J. M. Atwill, D. M. Ostermeier, and L. Richardson. I thank E. E. Provost and V. F. Nettles of the University of Georgia for their instruction and direction.

ABSTRACT

Reintroduction projects are complex; this project attempted to further management and research aspects regarding reintroduction of the red wolf. The management goal was to assess the feasibility of reestablishing the red wolf in Great Smoky Mountains National Park in TN and NC. The research goal comprised 2 objectives: 1) to assess the potential for physical interaction between 4 reintroduced red wolves (1 adult pair and 2 juvenile females) and 6 resident coyotes (5 male, 1 female) by radio-telemetry; 2) to assess the implementation of reintroduction procedures by methods of policy analysis and statistical process control. The combination of research and management impeded controlled scientific observation and resulted in general conclusions limited by the data-set. Pairwise comparisons of movements of study animals confirmed expectations that the red wolves would travel as a group and that coyotes would use separate areas from the red wolves and from other coyotes in the study. An index of overlap between the adult and juvenile red wolves, respectively, was 0.97, between 2 coyotes was 0.7, and in 2 different inter-specific comparisons was 0.19 and 0.38. The multiple-response permutation procedure judged physical interaction as likely in all 3 intra-specific comparisons [$0.25 \leq \text{all } \Pr(\leq \delta) \leq 0.45$] and as unlikely in both inter-specific comparisons [$\text{all } \Pr(\leq \delta) \leq 0.001$]. A Wilcoxon rank sums test of inter-animal distance concurred in these comparisons (all $p < 0.01$) except the

comparison between coyotes, in which observed inter-animal distance could not be distinguished from random expectation ($p=0.16$). Home ranges calculated by 5 methods ranged between 25-71 km² for red wolves and 7-30 km² for coyotes. A flow-chart of observed project procedures corresponded closely with planned procedures and a Pareto analysis suggested that following the release of red wolves the field team allocated more time and effort responding to depredations and undesirable movement patterns than to other problems such as equipment failure. The recovery program has developed a standard protocol for reintroduction projects and further specification of the procedures may reveal adjustments that will improve the process. The need for future reintroduction projects to improve the combination of research and management goals is discussed and techniques from statistical process control that may serve this need are presented.

PREFACE

Obtaining information is a matter of knowledge, using it is a matter of wisdom, and I have attempted to serve both matters in this paper. Many people I have encountered are interested in the ecology of wolves and most are eager either to give or receive information about them without separating fact from opinion. This places a burden on wildlife biologists to obtain sound information and use it well.

My own experience under this burden has shown me that in research and management we must remain flexible in our methods of investigation because familiar methods cannot always provide information quickly enough, nor definitively enough, and yet we must act. The Red Wolf Recovery Program has succeeded thus far, I believe, on such flexibility in methods and predilection for action. The research reported here suggests that more of the same is required to expand and improve the program. The challenge will be achieving efficiency: rapid accumulation of data, quick discrimination of fact, fiction, and hypothesis, prompt acceptance of truth, and appropriate action.

[The town] was then full of missionaries, prostitutes, mounted policemen, rum-runners, trappers, fur-smugglers, ordinary fur traders and other interesting characters, all of whom, so it developed, were authorities on wolves.

—Farley Mowat, Never Cry Wolf

"I, wisdom, dwell together with prudence...Blessed is the man who listens to me, watching daily at my doors, waiting at my doorway."

—Proverbs 8:12,34 NIV

Now this is the Law of the Jungle—as old and as true as the sky; And the Wolf that shall keep it may prosper, but the Wolf that shall break it must die.

—Kipling, The Second Jungle Book

...with a monarch's voice / Cry, "Havoc!" and let slip the dogs of war....

—Shakespeare, *Julius Caesar*

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I. INTRODUCTION

Reintroduction projects include legal, logistical, financial, political and social aspects in addition to the biological and ecological aspects (Gipps 1991, Peek et al. 1991). Until individuals of the target species are established in the wild, the limitations on the reintroduction project (e.g., policies, politics, and logistics) also are limiting factors for the population of the target species. As biologists and other professionals develop expertise in these management aspects of reintroduction, the research into ecological aspects of reestablishing animals in the wild require advancement also. This study represented an attempt to progress in both the management and research aspects of reintroduction of the red wolf (*Canis rufus*).

Goals were established by the Red Wolf Recovery Program (RWRP) of the U.S. Fish and Wildlife Service (USFWS) for both management and research. The stated management goal was to conduct a pilot-reintroduction of the red wolf in Great Smoky Mountains National Park (GSMNP), with cooperation from the National Park Service (NPS), to evaluate the feasibility of reestablishing this animal permanently (USFWS 1990). The research goal was composed of 2 objectives: 1) to assess the potential for physical interaction between reintroduced red wolves and resident coyotes (*Canis latrans*); and 2) to assess the implementation of reintroduction procedures in GSMNP (USFWS 1990). The objective to study physical interaction was the second phase of an exploration into

the ecological relationships between the 2 species. Crawford (1992) conducted the first phase, which focused on home range, abundance, and habitat use of resident coyotes prior to reintroduction of red wolves.

Assessment of interaction

The primary motivation for the research aspect of the project was the concern that reintroduced red wolves and their wild-born offspring would be placed in the wild without access to breeding partners of their own species (USFWS 1990). The immediate concern was that hybridization with coyotes might occur because the coyote now occurs in GSMNP and the range of the animal in this century has expanded throughout the United States (Hill et al. 1987, Nowak 1979, Gipson 1978).

The focus of the research objectives of this study was the potential for red wolves and coyotes to interact physically. Radio-telemetry was chosen to provide data that described the spatial relationship between members of the 2 species. Although radio-telemetry is not a direct measure of physical interaction, it permits an assessment of the necessary condition that 2 species use a common area. Furthermore, the need for studying other interactions, such as competition for food, den sites, or other habitat resources, would depend upon at least a general knowledge of the spatial relationships between the species.

This was the first opportunity to observe free-ranging red wolves sympatric with coyotes, although evidence now has been obtained of coyotes in the area of the previous reintroduction project at Alligator River National Wildlife Refuge (ARNWR) (M. K. Phillips, RWRP/USFWS, pers. comm.). Studies of spatial interaction among other carnivores have approached the question by estimating home range or plotting overlap of home-range estimates (Harrison et al. 1989, Sargeant and Allen 1989, Major and Sherburne 1987, Sargeant et al. 1987, Fuller and Keith 1981). A major limitation of these studies is the subjectivity of home-range estimates. White and Garrott (1990) point out that every non-parametric estimator requires some subjectivity in the calculations. For example, the oldest and simplest method, the minimum convex polygon (Mohr 1947), requires the choice of creating corners of $\geq 180^\circ$ at the outermost location estimates. Harvey and Barbour (1965) demonstrated how that choice could be reversed in the calculation of concave polygons. The contemporary method of harmonic mean (Dixon and Chapman 1980) requires the subjective choice of a density of nodes from which distances to location estimates are calculated for use in the harmonic mean statistic. Higher densities result in more detailed probability isopleths.

Future progress in recovery of the endangered red wolf likely will raise the question of how this canid will behave in a community with other canids of North America in addition to the coyote. Studies of red foxes (*Vulpes vulpes*), coyotes, and grey wolves (*Canis lupus*) have suggested that these 3 canids may relate to

each other hierarchically, in a relationship where the larger species excludes, or at least impinges upon the spatial use of the smaller species (Dekker 1983, Sargeant 1982, Johnson and Sargeant 1977, Linhart and Robinson 1972). Grey wolves may exclude coyotes; coyotes may, at least, restrict movements of red fox (Paquet 1991, Harrison et al. 1989, Theberge and Wedeles 1989, Carbyn 1982, Fuller and Keith 1981, Berg and Chesness 1978, Mech 1970). These findings support speculation that the red wolf, which is intermediate in size between the coyote and grey wolf, will either restrict the movements of, or displace, the coyote.

Populations of coyotes have been established in the southeastern U.S. in recent years in response, at least in part, to human influence (Hill et al. 1987). If red wolf movements inhibit coyote spatial use, then perhaps the distribution of red fox will expand in the region following reestablishment of red wolves.

Within the southeastern U.S., the spatial use of the red wolf is important for at least 2 reasons in addition to the possible effect on populations of resident canids: 1) if behavioral differences are observed between red wolves and coyotes in the wild, this information may clarify questions of taxonomy; 2) if red wolves establish movement patterns in proximity to pets and livestock, the acceptability of the reintroduction projects in local communities could be compromised by the realizations of fears of depredations (Fritts and Paul 1989).

First, the national debate over the Endangered Species Act has focused criticism on recovery programs for species with dubious taxonomic distinctiveness

(Gittleman and Pimm 1991, O'Brien and Mayr 1991). Genetic tests have failed to determine whether the red wolf originated as a grey wolf-coyote hybrid or as a distinct form that has hybridized recently with the coyote and the grey wolf (Wayne and Jenks 1991). Dowling et al. (1992) emphasize that these genetic tests are based on a relatively limited percentage of the genome and are properly interpreted as having failed to collect sufficient evidence to reject the null hypothesis of no difference between the red wolf and coyote as species. An additional confusion of the taxonomic question is the problem of defining and interpreting the concept of species (O'Brien and Mayr 1991, Waples 1991). The genotypic information on the taxonomic question might be furthered with phenotypic information such as the comparative behavior between red wolves and coyotes in free-ranging conditions.

Second, although fear for pets and livestock is a common feature of public discussion of wolf reintroduction, the sparse data reported on the subject suggests that these fears can be overcome through public education. Although grey wolves have attacked and killed both pets (dogs) and livestock, these events are believed to be rare and controllable (Fritts and Paul 1989). USFWS (1990) reported that the success in the reintroduction of red wolf thus far is explainable by the efforts to allay these fears through the dissemination of factual information about canids, especially by openly discussing and planning contingencies for the potential for red wolves to kill livestock.

Assessment of project procedure

The secondary objective within the research aspect of this project was to assess the reintroduction procedure. Being the first release of red wolves into an area known to support coyotes, and also being an emotional issue with public and private landowners and visitors, the project was directed by case-by-case planning and problem solving alongside of which the assessment was developed. This incremental approach has evolved throughout the history of the RWRP.

After the last known red wolves were captured from the wild and established as a captive population, attempts to reintroduce began in the late 1970s. Mated pairs of adult red wolves from the remnant group captured from the wild were released in the first experiments (Carley 1981, Carley 1979). Each of these 1-year trials on Bulls Island, Cape Romain National Wildlife Refuge, near Charleston S.C., were concluded with the successful recapture of the animals.

In 1981, an attempt was made to reintroduce red wolves on the mainland at the Tennessee Valley Authority Land Between the Lakes property on the border of Tennessee and Kentucky. The project was abandoned as concern and opposition among local livestock operators, hunters, and environmentalists mounted (Moore and Smith 1991). RWRP personnel believe the ultimate cause of this failure was the lack of attempt to educate the public about the project and about the red wolf.

These lessons were applied to the planned reintroduction at ARNWR, which was undertaken with the belief that disseminating factual information is of

paramount importance (Parker 1987). Beginning with the ARNWR reintroduction, a general structure of operational guidelines and procedures for reintroduction was established that was published in the planning documents for the reintroductions at both ARNWR and GSMNP. Parts of this procedure were completed prior to the beginning of this study, although exact dates are not available (Table 1).

Whereas the RWRP determined that the dissemination of information was critical to the feasibility of a reintroduction project, research in procedures of natural resource management programs, and reintroduction programs in particular, has identified the gathering and use of information as a key to success (Clark and Harvey 1991, Clark et al. 1989, Ounsted 1991, Chivers 1991, Walters 1986, Janis 1971). Clarke and McCool (1985) drew attention to the need to understand organizational structure and function as a means of better managing natural resources. Even though most natural resource management is conducted under authority of public policy, some management activities can be analyzed with the same quantitative methods applied to free enterprise, even though the motivations for policy and business differ (Dykstra 1984).

The information needs of project assessments can be met with techniques and analyses from the fields of policy analysis and statistical process control. The case study is a common policy-analysis tool for documenting projects and has been applied to reintroduction projects (Gipps 1991, Clark and Harvey 1991).

Table 1. Operational guidelines and procedures for red wolf reintroductions as adapted for the pilot-reintroduction in GSMNP (USFWS 1990) and dates of initiation that were recorded (C. Lucash, USFWS/RWRP, pers. comm.).

Initial preparations (initiated January 1989)

public information

- form information team of National Park Service (NPS) and Fish and Wildlife Service (USFWS) personnel
- develop methodology that "optimizes dissemination of information" through responses to direct inquiries, and through local outdoor writers and newscasters.

public meetings

- inform those attending and record comments regarding the project
- incorporate results in final plans with consultation among directors and other personnel of NPS, USFWS and state wildlife agencies

Reestablishment Plan (initiated mid-1989)

administrative efforts

- comply with federal regulations: develop environmental assessment; develop rulemaking for Section-10 experimental / non-essential designation of study animals (final rule published October 1991); complete Section-7 consultation
- arrange inter-agency responsibilities: funding and budgeting commitments, roles in compliance with federal regulations, conformation between RWRP procedures and GSMNP regulations
- contract with a research institution (e.g., university) for monitoring of project

public information program

- plan for attentive coverage by news media between the approval of the project and the beginning of field procedures, after which coverage likely will taper off

preparation of release site (initiated December 1990)

- construct acclimation pens
- train personnel in care and handling of red wolves
- develop and test radio-tracking system

resident prey and predator surveys (initiated January 1990)

- estimate ecological parameters of important prey and resident predator populations

release strategy

- 5-6 month acclimation period (initiated January 1991)
- spring-season release to coincide with higher abundance of prey

recapture techniques and procedures

- secure equipment: leg-hold traps modified with tranquilizer tabs and radio beacons, dart-collar (Mech et al. 1984)
- train personnel

Effects of wolf establishment

- develop means for gathering information during the project, e.g., interactions between reintroduced red wolves and 1) coyotes, 2) livestock
-

Policy analysis and statistical process control provide alternative means of organizing observations, i.e., alternative paradigms (Kuhn 1970). Stokey and Zeckhauser (1978) describe policy analysis as a 5-step process: 1) define problem and objectives; 2) propose alternative solutions; 3) predict consequences; 4) evaluate consequences; 5) choose one of the alternative solutions. The teaching materials of the Institutes for Productivity Through Quality of the University of Tennessee (U.T. 1992) describe a similar pattern for statistical process control: 1) defining the problem; 2) attempting remedial modifications; 3) documenting improvement; 4) maintaining improvement and searching for the next problem. These paradigms resemble the standard scientific paradigm (Table 2).

This assessment of project procedure drew from both policy analysis and statistical process control. Because policy analysis primarily is prospective, only the first step, which is descriptive evaluation, was applied by using the techniques of case study (Starling 1988) and flow-charting (Stokey and Zeckhauser 1978). Statistical process control combines evaluation with manipulations of the process, but only the evaluation technique of Pareto diagramming (U. T. 1992) was applied because the scope of the project did not include subsequent reintroduction attempts during which the outcome of modifications to the process could be measured.

Table 2. Comparison of paradigms in research, policy analysis, and statistical process control.

Research paradigm.	Policy analysis.	Statistical process control.
Define question.	Define problem and objectives.	Diagnose the problem most limiting to production or progress.
Propose answer (hypothesis) and design experiments under which it can be evaluated.	Propose alternative solutions.	Attempt remedial activities.
Collect and analyze data.	Predict consequences.	Continue attempts at remediation until improvement is demonstrated.
State conclusions with respect to the hypothesis.	Evaluate consequences.	Establish the remedial activity in operating procedure.
Restate the initial question in light of conclusions.	Choose one of the alternative solutions.	Search for the new most limiting problem.

II. STUDY AREA

GSMNP is located in eastern Tennessee and western North Carolina (Fig.

- 1). This work took place in the northwestern area of the park, centered in Cades Cove and bounded on the north and west by 4 other coves outside the park (Fig.
- 2). The coves are distinguished from the predominant terrain of steep slopes and forest cover by relatively level topography and open cover types. The coves are maintained in fescue pastures or open fields interspersed with woodlots.

The ridge and valley terrain in the area reaches elevations from 266 to 2024 m (Clingman's Dome). At lower elevations, rainfall is 127-152 cm/yr; above 1800 m, rainfall increases to approximately 230 cm/yr (Shanks 1954). The cove areas within the study area—estimated by dot grid—cover approximately 1623 ha (Tuckaleechee Cove), 1434 ha (Wear Cove), 978 ha (Cades Cove), 725 ha (West Miller Cove), and 347 ha (Happy Valley), totaling 5107 ha.

Approximately 1,300 flowering plants and 2,400 non-flowering plants grow in the area (King and Stupka 1950). The area supports 59 species of mammals, not including 6 species believed to be extirpated nor including coyotes, which are believed to have entered the park in 1985 (Crawford 1992, Linzey and Linzey 1971). Potential prey items for canids include white-tailed deer (*Odocoileus virginianus*), ground-hog (*Marmota monax*), wild hog (*Sus scrofa*), raccoon (*Procyon lotor*), cottontail rabbit (*Sylvilagus floridanus*), and small rodents. Approximately 600 black angus cattle (*Bos taurus*) graze in Cades Cove.

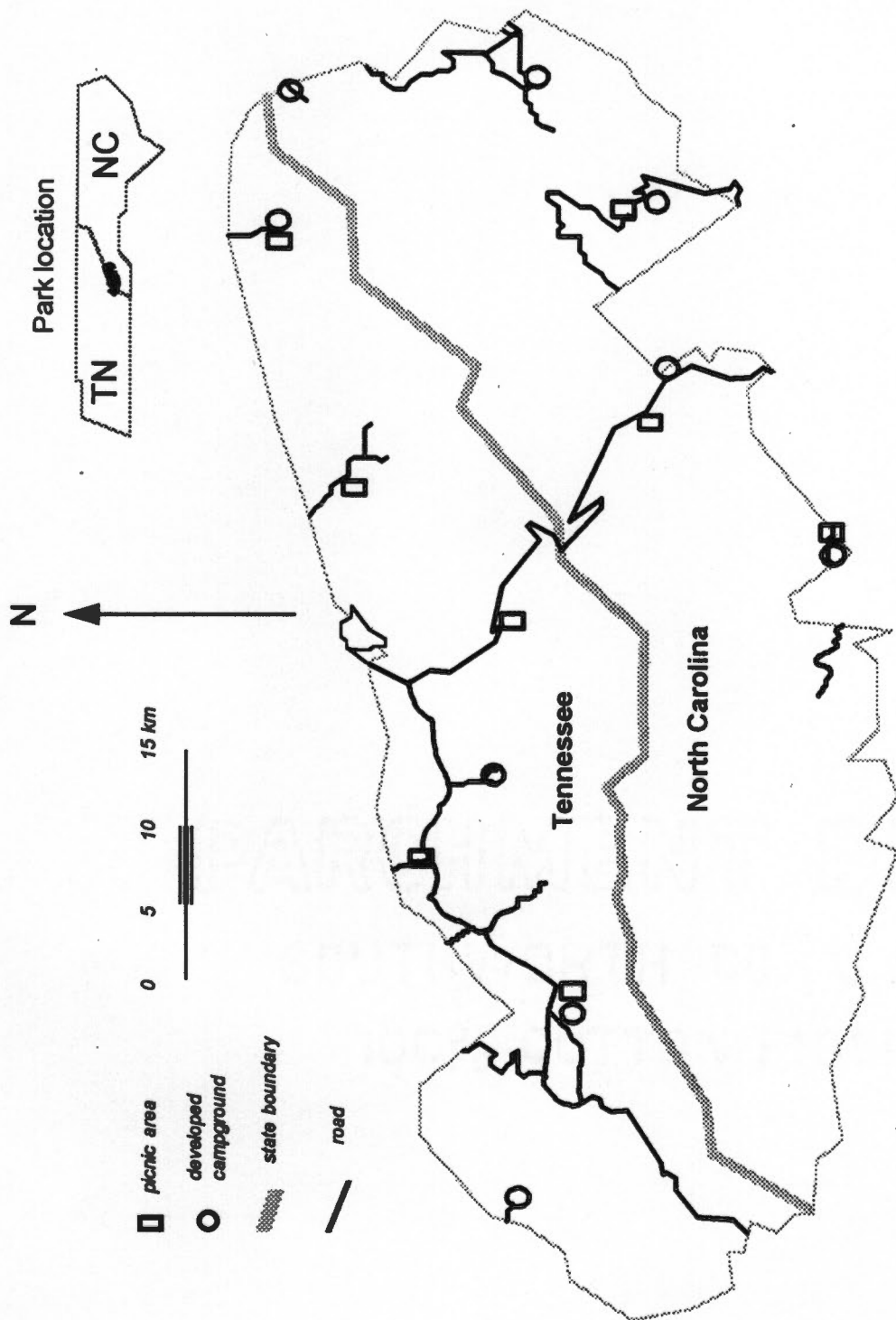


Figure 1. Great Smoky Mountains National Park.

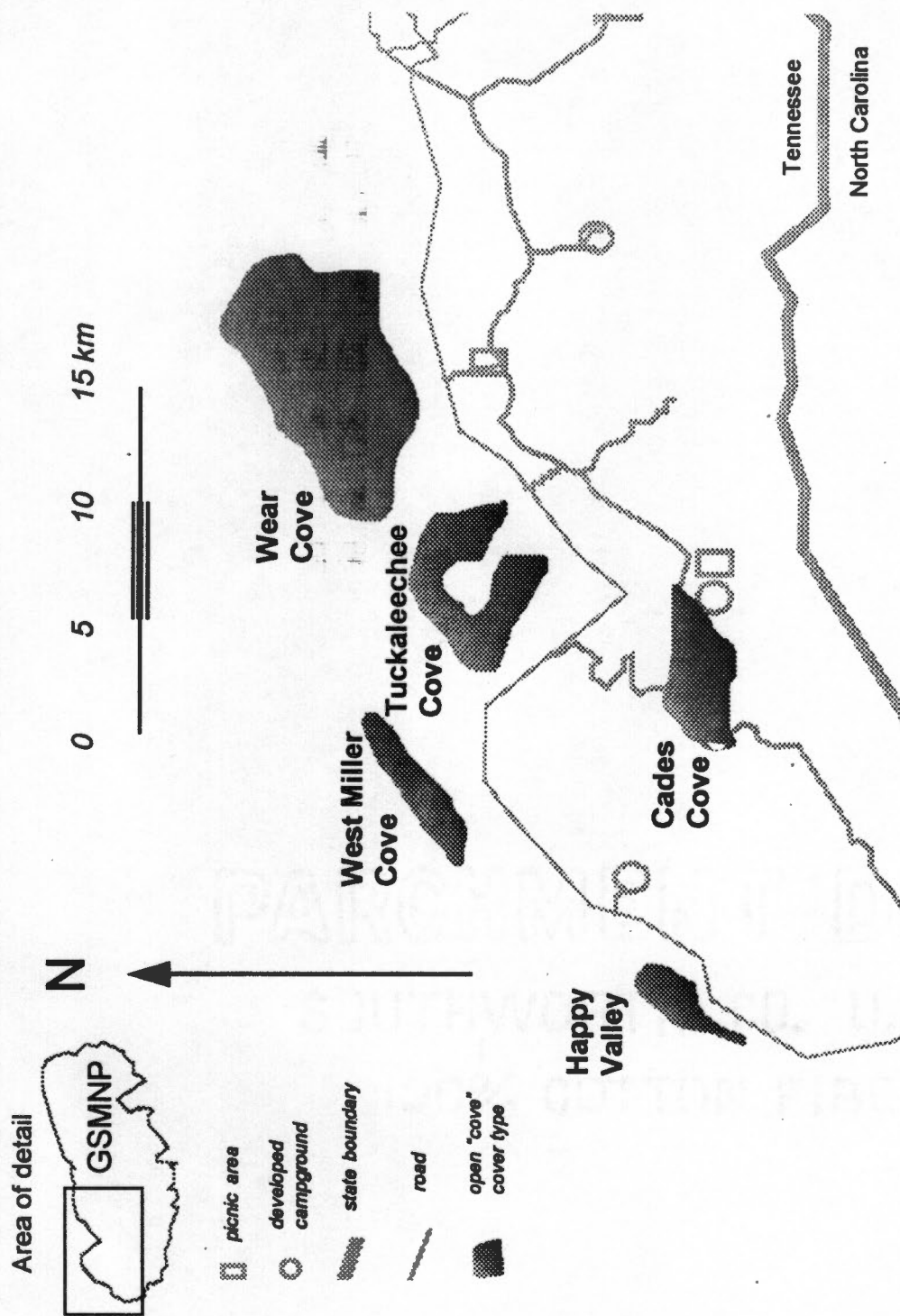


Figure 2. Study area in northwestern GSMNP and adjacent private lands.

III. METHODS

Field personnel numbered between 3 and 5 during the study; prior to release of red wolves, tracking was conducted by 1 person. For continuity in observing the coyotes in the study, the identification numbers used by Crawford (1992) were adopted. For clarity in referring to study animals, the prefixes RAM, RAF, RJF will represent red wolf adult male, female, and red wolf juvenile female, respectively. CAM, CAF, and CJM represent the corresponding age and sex categories for coyotes.

Prior to initial release, 2 pair of adult red wolves were delivered to GSMNP on 28 January 1991, and held in separate acclimation pens approximately 50 m apart in a backcountry site in the vicinity of Cades Cove. The acclimation pens were constructed of chain-link fencing of 4 sides 15.2 m long, 3 m high with 1 m of additional fencing angled inward at the top and skirting the ground inside the pen at the bottom. After 1 pair produced a litter (2 male, 3 female), the family group was divided into 4 animals for soft-release (the adult pair and 2 female juveniles) and 3 animals were returned to the captive-breeding / reintroduction facility at ARNWR. When red wolves were captured following the release, they were held in the same acclimation pen from which they had been previously released.

Procedures for holding red wolves in and releasing from an acclimation pen, termed "soft-release", was developed at ARNWR (Phillips 1987). Based on

experience with previous soft-releases, the acclimation period was scheduled to last 6 months (USFWS 1990), but release of the red wolves was delayed from the target date of 7/91 until 11/91 by the procedure of obtaining experimental / non-essential population status under the Endangered Species Act (Parker and Phillips 1991). At the time of release, project personnel visited the pen as per the regular feeding schedule but locked the pen door in the open position before leaving. The red wolves were left to venture out and return to the pen freely.

The methods of obtaining and handling coyotes followed Crawford (1992). Trapping continued using Victor Soft-Catch #3 steel leg-hold traps in sets targeted for coyotes; for targeting red wolves, #4 steel leg-hold traps were used. Sets varied among dirt-hole, scent post, and carcass baits and lures and were placed throughout Cades Cove along creeks and paths and near the acclimation pens. Five of the coyotes monitored had been captured during the initial phase of the study (Crawford 1992), 1 coyote was captured during this phase. Trap lines were conducted by RWRP personnel in Cades Cove sporadically during the acclimation period, but detailed records were not kept. I conducted 252 trap nights in June, 1991, along a common travel route of CAM-4. These traps were unsuccessful except for the capture of 3 turkey vultures (*Cathartes aura*) which were captured near carcass sets.

Location estimation

Ten animals were radio-tracked (4 red wolves and 6 coyotes, see Table 3) over 18 months (4/91 - 9/92) (Fig. 3). Study animals were instrumented with radio-transmitters in 3 different ways. Transmitters were collar-mounted, inter-peritoneal, and dart-collar-mounted as described by Mech et al. (1984) and further developed by Wild-Link, Inc. (Brooklyn Park, MN). The use of the dart collar was motivated by the concern of opponents to the project about the feasibility of retrieving study animals, despite the high success rate of capturing red wolves at ARNWR by leg-hold trap (USFWS 1990). Red wolf juveniles and coyotes were instrumented with Telonics, Inc. (Mesa, AZ), collars and the red wolf juveniles also were implanted with inter-peritoneal transmitters. Adult red wolves were implanted and wore the dart-collars.

Locations were estimated most often by individual field personnel travelling by pick-up truck using either a roof-mounted 5-element antenna (Wildlife Materials, Inc., Carbondale, IL) or a hand-held 2-element (yagi) antenna and a Telonics, Inc., TR2 receiver. Azimuths were estimated in the direction of maximum signal strength by hand-held compass. Locations were estimated also from fixed-wing aircraft (Cessna model 172) using a t-switch to monitor signals either simultaneously or alternatively from the yagi antennas mounted on the wing-struts. USGS 7.5-minute topographic quadrangle maps were used to record animal locations estimated from the air and opportunistic visual observations from

Table 3. Study animals handled in GSMNP and vicinity during the pilot-reintroduction of red wolves 1990-1991. Identification codes: R=red wolf; C=coyote / A=adult, J=juvenile / M=male, F=female.

Species	Age	Sex	I.d. # ^a	Date	Handling
C	A	M	2	3/27/90	trap-release ^b
C	A	M	3	4/11/90	trap-release ^b
C	A	M	4	4/13/90	trap-release ^b
C	A	M	5	11/7/90	trap-release ^b
C	A	F	6	1/9/91	trap-release ^b
C	J	M	7	10/22/91	trap-release
R	A	M	219	11/12/91	soft-release
R	A	F	303	11/12/91	soft-release
R	J	F	467	11/12/91	soft-release
R	J	F	468	11/12/91	soft-release

^aIdentification of coyotes follows Crawford (1992), red wolf numbers follow red wolf captive breeding stud-book.

^bcapture reported by Crawford (1992).

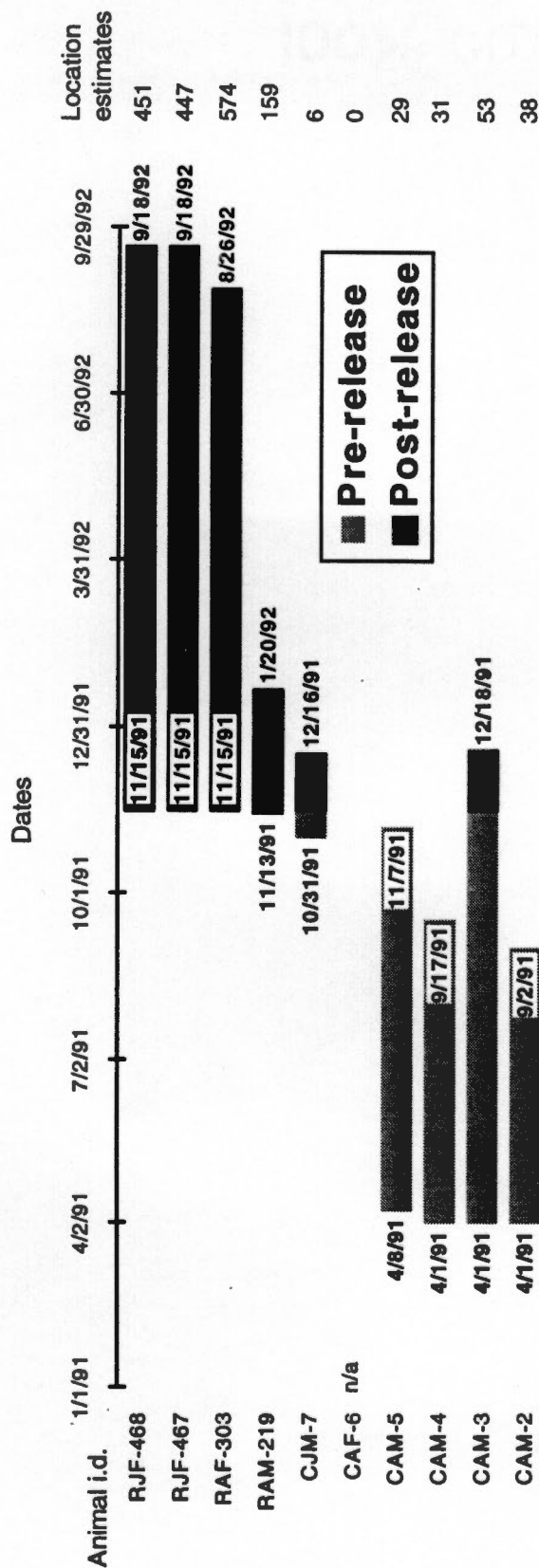


Figure 3. Beginning and ending dates of radio-tracking and resulting location estimates with respect to date of initial soft-release of red wolves (12 Nov 91) during pilot-reintroduction in GSMNP.

the ground, and also to estimate position of telemetry receiver-locations. A Universal Transverse Mercator (UTM) coordinate grid (Forestry Suppliers, Inc. Jackson, MS) was used to interpolate the UTM coordinates from the maps to the nearest 10 m.

The observation schedule was determined based on the need to respond quickly to dispersals of the red wolves and to obtain as large a sample as possible for the coyotes, which had dispersed from the main study area. Coyotes were located 1-3 times per week; red wolves were located 10-20 times per week. Triangulations were calculated from pairs of azimuths estimated from ≥ 2 receiver locations selected in attempts to minimize both the time between azimuth observations and the range from which the azimuths were measured. When multiple location-estimates were attainable for a particular animal's location, the triangulation with angle of intersection nearest to 90° was chosen. From the air, search patterns were followed as suggested by Gilmer et al. (1983). Calculation of location-estimates was performed with the "consecutive" triangulation procedure in TELEM88 software (Coleman and Jones 1988), selecting azimuths taken within 20 minutes of each other and intersecting at $[30^\circ \leq \theta \leq 150^\circ]$.

Accuracy of locations was assessed by estimating the location of collars placed within the study area as beacons and by estimating the location of collars carried into backcountry locations. The locations of the backcountry collars were estimated by a hand-held global positioning system (Magellan Systems Co.,

Monrovia, CA) and the locations of the beacons were estimated by interpolation from the topographic maps. These field tests resulted in mean angular deviation = 1° and standard deviation = 26° . This high variation probably was attributable to the uncorrected global-positioning system estimates of the backcountry collars (D. A. Buehler, U.T., pers. comm.) and generated a highly-skewed distribution of error polygons (min. < 1 , median = 6, max. = 99 km^2).

Spatial analyses

Analyses of radio-telemetry data were performed at two levels, based on the summary of analytical methods described by White and Garrott (1990): 1) estimates of home range, for which the range estimate is treated as a statistic for summarizing and comparing the movements of various animals or groups of animals, and 2) analyses of simple movements, where the sampling unit is the individual location-estimate. The purposes of these spatial analyses were to describe the spatial use and, with the analysis of simple movements, to support inferences about the spatial interaction between the 2 species.

Computations were performed using commercial software and original code. TELEM88 (v.01.92, Coleman and Jones 1988) was used to calculate home-range estimates; analyses of simple movements were performed with IDRISI geographic information software (v.4.0, Eastman 1992), BLOSSOM Statistical

Software (v.1290, Slauson et al. 1991), and original code for SAS (v.6.04, SAS 1987) composed by J. Clark (Nat. Biol. Survey, pers. comm., Appendix A).

Analyses were based on the comprehensive data-set describing each animal and also on 4 seasonal sub-sets following Smith et al. (1981) and Laundré and Keller (1984): pair formation (1 Jan - 15 Mar); gestation (16 Mar - 30 Apr); pup-raising (1 May - 31 Jul); dispersal (1 Aug - 31 Dec).

The primary purpose of calculating home-range estimates was to generalize and describe the tracking data in addition to providing a measurement for comparison with other studies. Because of the subjectivity and lack of error measurement in the home-range estimators, I calculated several so that the group of estimates would provide some sense of a range in which a true value might lie. Furthermore, because red wolves may begin their exploration of territory from a soft-release site by following a radiating pattern, I included the concave polygon estimate (Harvey and Barbour 1965).

Seven estimates of comprehensive and seasonal home ranges were calculated for each animal. Four of the 7 estimates were based on minimum area polygons: convex polygon (Mohr 1947) and concave polygon (Harvey and Barbour 1965). Each of these polygon estimates were calculated twice: first using 100% of the location estimates and then using only the center-most 95% (Bowen 1982). The remaining 3 of the 7 estimates were isopleths (i.e., areas

defined by probability of use = 50%, 80%, and 95%) calculated by the harmonic mean method (Dixon and Chapman 1980).

Two major problems prevented the collection of substantial data. First, 4 coyotes captured in the Cades Cove area during the previous study (Crawford 1992) established regular movement patterns beyond the movements of the released red wolves. Three of these 4 were males that dispersed to areas northeast of Cades Cove, the fourth animal (the only female coyote in the sample) dispersed to the southwest and was contacted only by a single azimuth. The second problem was the delay of the release of red wolves from mid-July until 12 Nov 91, by which time the transmitters on the coyotes remaining in Cades Cove (CAM-3 and CJM-7) nearly had expired (Fig. 3).

CJM-7 was located 6 times, which raised a question whether these data adequately represented the home range of the animal. The effect of sample size on accuracy of the estimate is unknown because home range estimators are not associated with measures of error. The effect of sample size on comparability of estimates, however, seems clearer. Estimates probably are not comparable when differing widely in sample size (Jennrich and Turner 1969). In keeping with the purpose of home-range estimation in this study as a method of data description, I excluded CJM-7 from tabulations of comprehensive home ranges because the animal was tracked only during the dispersal season of 1991. Within this season, the home-range estimates for CJM-7 fell toward the center of the distribution.

The data on RAM-219 also were curtailed as this animal was recaptured from the wild and withdrawn from the project on 21 Jan 92. On this date, RAM-219 was located on private land in the vicinity of a reported depredation on domestic turkeys. RWRP personnel used the dart-collar to anesthetize the animal and, upon retrieving the animal, found sign (e.g., turkey feathers, regurgitated turkey parts) that confirmed RAM-219 was responsible for the depredation.

The analyses of simple movements were conducted on a sequence of comparisons between pairs of study animals (Table 4). These comparisons were established to provide a basis of current knowledge of these species against which to compare the results of the simple-movement analyses. The comparisons were designed to range in expectation of physical interaction from likely (comparison 1) to unlikely (comparison 5). The basis in knowledge of the red wolf for the comparisons was the consensus among RWRP personnel that red wolves travel in family groups (USFWS 1990); therefore, juvenile red wolves were expected to interact most of all pairs, and adult red wolves were expected to interact less. The known solitary habits of the coyote (Beckoff and Wells 1986) and the expectation that red wolves and coyotes would not interact physically was used to propose the remaining comparisons.

An index was calculated to quantify overlap, 1 hypothesis test was run of the relationship between distributions of locations, and 1 hypothesis test of the relationship between inter-animal distance and distance between randomly

Table 4. Comparisons for simple-movement analyses of red wolves and coyotes in GSMNP from 1 Aug - 31 Dec 91 (dispersal season). I.d. number prefixes: R=red wolf, C=coyote / A=adult, J=juvenile / M=male, F=female.

Comparison number	Description: animal i.d. (sample size of location estimates)
1	RJF-467 (59) and RJF-468 (64)
2	RAM-219 (118) and RAF-303 (91)
3	CAM-3 (27) and CJM-7 (6)
4	RAM-219 (118) and CAM-3 (27)
5	CJM-7 (6) and RJF-467 (59)

associated location estimates. The analyses of simple movements were focused on the animals in the Cades Cove area during the dispersal season of 1991; this was the only period of time in which red wolves and coyotes were tracked simultaneously. Due to the problems in data collection discussed previously, the sample sizes for these tests were uneven in favor of red wolves (Table 4).

No rejection region was established for either of the hypothesis tests because a calculated level of significance is more informative at this stage of the investigation of red wolf spatial use. Because this was the first time these tests were conducted on reintroduced red wolves, there is no repeated sampling context to give meaning to a decision rule such as $\alpha=0.05$. Such a rule would state that a test is too risky if truly indistinguishable movement patterns are erroneously declared separate on an average of once in 20 reintroductions or 20 applications of

the test within a reintroduction. Reintroductions are not taking place at a rate high enough nor are data being collected sufficiently to support this many tests and give the rule meaning. Furthermore, because the outcomes of the tests have not been related to the probability of hybridization, fighting, or other physical interaction, neither can the potential for erroneous results be related to these possible outcomes. Alternatively, the levels of significance provide a measure of the weight of evidence that the animals traveled separately, which is useful in answering the question of interest: whether physical interaction was likely during this reintroduction project.

Quantification of overlap. According to the expectations used to develop the comparisons, a measure of overlap should decrease from comparison 1 to 5. Whereas overlap has in previous studies been quantified as the area common to ≥ 2 home-range estimates, that method includes the subjectivity of the home-range estimate (White and Garrott 1990). Powell (1987) presented an alternative method based on the measured resolution of the radio-telemetry observations. Following this method, which is an adaptation of the niche-overlap equation reported by Pianka (1974), I quantified overlap by developing a grid-cell map composed of relative frequencies of occurrence in each block.

First I calculated a grid-size based on telemetry error to represent the resolution of the telemetry measurement system. I constructed error blocks by doubling the median straight-line error for the diagonal of the block, following the

reasoning of Saltz and Alkon (1985). A grid of these 0.67-km² blocks was then overlaid on a map of the locations of each animal; then the relative frequency of animal locations falling within each block was calculated. I interpolated the values of the resulting utilization distribution to assign values to empty blocks through which the animal was assumed to have traveled. The frequencies represented the probability that the animal used that block.

Using these maps of probabilities, the niche-overlap index reported by Pianka (1974) was adapted after Powell (1987) as follows:

$$O = \frac{\sum^k (p_{1k} \cdot p_{2k})}{\sqrt{(\sum^k p_{1k}^2) (\sum^k p_{2k}^2)}}$$

where $k=1$ to the number of blocks and p_{1k} and p_{2k} are the respective probabilities of animal 1 and 2 occupying block k .

The index of overlap, O , is interpreted as a percentage of overlap that incorporates the relative importance of the overlapping regions to the animals in the comparison. The index is not interpreted as a probability of interaction because the measure does not indicate the probability that the 2 animals would occupy a given block simultaneously.

Test of location-distribution. Another expectation following from the proposed comparisons is that the respective scatter plots of location-estimates for the animals would be distinguishable spatially. A test of this distribution of point-estimates, the Multiple-response Permutation Procedure, as originally reported by Mielke and Berry (1982), is based on a measure of the dispersion in the scatters of location-estimates observed. By comparing the scatters, the test challenges the null hypothesis that the 2 samples were drawn from a common distribution of locations.

The mechanics of the test are as follows. If the locations in 2 samples are intermingled thoroughly, then the measure of dispersion in sample 1 changes only slightly if 1 or more locations from the second sample are reclassified as belonging to the first. The same change between samples distributed differently, however, drastically changes the value of dispersion because the foreign location likely represents an outlier.

The analysis software BLOSSOM (Slauson et al. 1991), calculates dispersion as the average distance between all possible pairs within each sample, and represents these values by delta 1 (δ_1) and delta 2 (δ_2). The average of the 2 delta values, weighted by the number of locations in the respective samples, is the observed delta (δ_0). After calculating δ_0 , the procedure simulates all possible reassignments of 1 or more locations between the samples. A value of δ is calculated for each. The number of these permutations is found by the equation:

(total locations)!/(locations in group 1)! • (locations in group 2)!. For example, comparison 1 involves 59 and 64 location-estimates of RJF-467 and RJF-468, respectively. The total reassignments of those 123 locations to groups of 59 and 64 is: $123! / (59! \cdot 64!) = 6.902 \cdot 10^{35}$.

In the randomization distribution that is created, each calculated value of δ is assigned an equal probability, which is the inverse of the total reassignment permutations. Between 2 animals that travel together, the measure of dispersion for each permutation remains approximately the same and would compose a large grouping in the center of the distribution that includes the observed value. On the other hand, between 2 animals that travel separately, the δ_o falls below nearly all the generated δ . When this is the case, the probability of observing a greater value will be very high, representing good evidence against the null hypothesis.

Test of inter-animal distance. A more specific test of potential for physical interaction was conducted to determine whether the distances between animals at a given time were closer or farther apart than would be expected at random. The expectation that average distances would be smaller than random starting with comparison 1 and farther than random in comparison 5 would account for the possibility that these 2 species used common territory but avoided proximity to each other.

This was tested by comparing the distribution of inter-animal distances among locations paired in time sequence against a distribution of inter-animal

distances among locations randomly associated. The sample size of paired locations was originally composed of locations observed within 8 hours of each other, and was increased by pairing observations taken within 24 hours of each other. This change did not affect the outcome of the tests. I compared the distributions with the Wilcoxon rank sums test of 2 distributions because this test assumes no specific distribution for distances and because the observed distributions of inter-animal distances were both skewed and heavy-tailed (i.e., included outliers). Under these violations of the normality assumption required for 2-sample t-tests, the rank sums test is more powerful (i.e., more likely to detect a difference that truly exists) (Ott 1988).

Assessment of project procedure

Attempts to assess procedure began with development of a flow-chart (Stokey and Zeckhauser 1978) by reconciling the expected procedures in the RWRP planning documents (Table 1) and the observed procedures in a case study analysis (Starling 1988) of the events and activities during the pilot-reintroduction. The actions and events relating to behavior of the red wolves were the focus of the case study approach because even though project personnel performed a variety of tasks, the interactions between red wolves, coyotes, livestock, and people was central to the outcome of the pilot-reintroduction. The director of field operations used a personal computer to record actions and events in diary format. The entries

were composed based on firsthand experience and communication among other members of the field team.

Entries were categorized and tabulated to reflect the relative importance of various events and activities. Because this analysis was developed concurrently with the progress of the field-work, the tally-data were the only empirical basis for measurement in this assessment. Normally, the entire field-team participates in the development of the measurements and sampling protocol, and in alterations of the measurements as needs for information are clarified (U. T. 1992).

A Pareto diagram was used as the analytical tool for comparing the relative importance of categories of events and activities (U. T. 1992). This analysis is based on the Pareto principle, commonly known as the "eighty-twenty" or "sixty-forty" rule, which states that a majority of observed results follow from a minority of causes. The purpose of the analysis is to identify the most troubling difficulty in the procedure, remediate its cause, and then repeat the analysis to find the next-most-troubling difficulty. To measure difficulty requires that the comparison be based on an all-encompassing measure of progress (e.g., the financial "bottom line" in an accounting statement). I used log-entries as a measure of the time and effort of the field team, but if this analysis had been fully applied, a measure of an ecological result might have been developed, perhaps to indicate the survivability of red wolves after release.

IV. RESULTS

Location estimation

Location estimates were obtained for collared animals except CAF-6: 1631 location-estimates were obtained for red wolves, 157 for coyotes, totaling 1788 location-estimates. The samples of location-estimates obtained for individual animals are listed in Figure 3.

Spatial analyses

The overall spatial use of all animals during the study is summarized in the plot of minimum convex polygon home range estimates (Fig. 4). The 95% minimum convex polygon estimates (Bowen 1982) were used for this display because they best describe the relationship among the areas where the study animals were most often located. The comprehensive home-range estimates excluding the 80% and 50% harmonic mean isopleths ranged between 25-71 km² for red wolves and 7-30 km² for coyotes. These estimates varied less and maintained more consistent medians among the red wolves than among the coyotes (Fig. 5). This pattern remained in the analysis of range-estimates by season (Table 5). Some variability among the range estimates resulted from the peculiarity of the harmonic mean estimator when location estimates are relatively clumped.

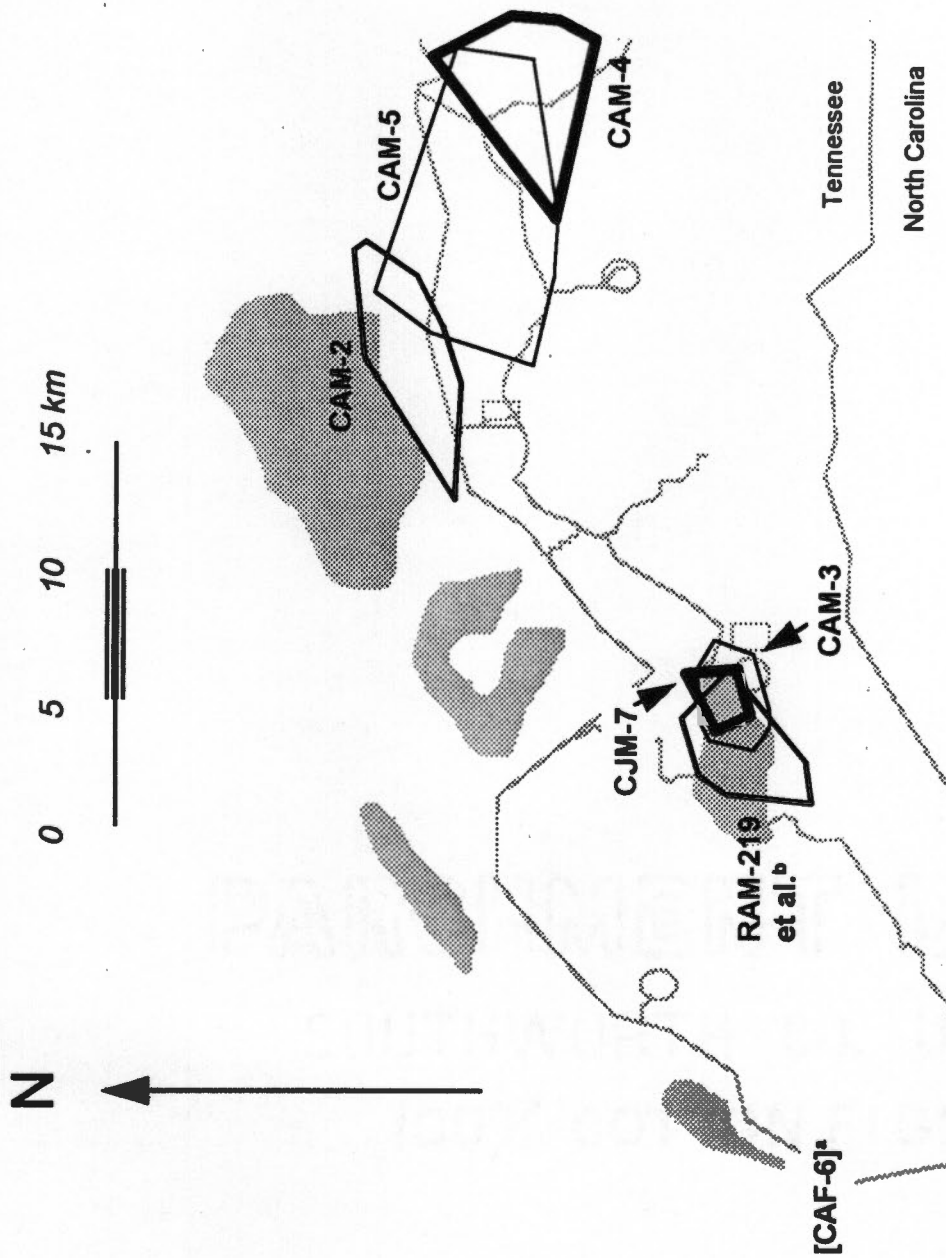


Figure 4. Comprehensive minimum convex polygons (95% of location estimates) of study animals during pilot-reintroduction of red wolves in GSMNP. ^aIn this vicinity a faint signal from CAF-6 was received only once; ^bthe RAM-219 polygon encompassed those of the other red wolves.

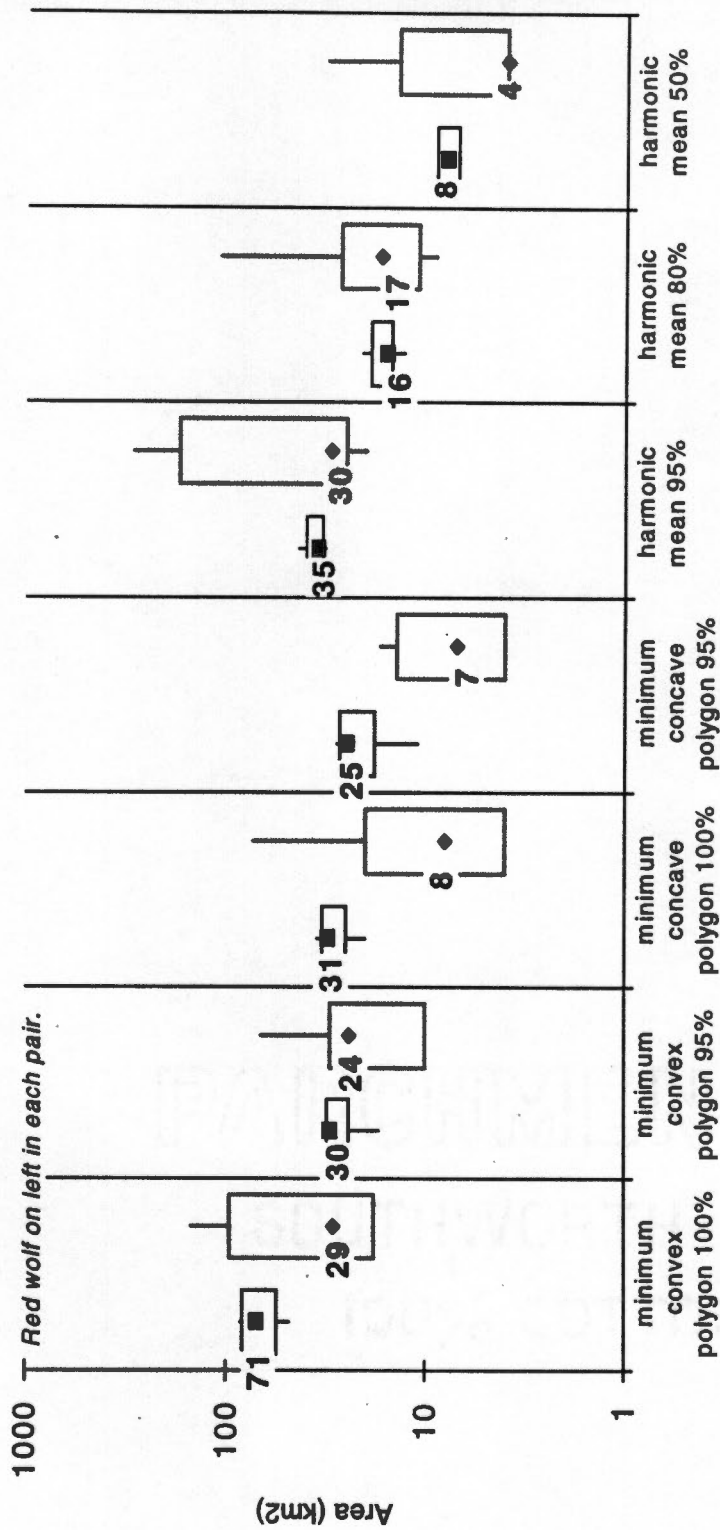


Figure 5. Box-and-whisker plots and labeled medians of comprehensive home-range estimates by method and species of study animals during pilot-reintroduction of red wolves in GSMNP (km², log scale).

Table 5. Median home range estimates (km²) of red wolves and coyotes by season, species, and method during pilot-reintroduction of red wolves in GSMNP.

Method	% ^a	spp	comp	G'91	PR'91	D'91	PF'92	G'92	PR'92	D'92
MCVP	100	R	71			27	30	23	27	11
	100	C	30	8	14	21				
MCVP	95	R	30			11	16	20	27	0
	95	C	24	1	14	5				
MCCP	100	R	31			9	5	15	21	0
	100	C	8	0	2	3				
MCCP	95	R	25			6	4	12	19	0
	95	C	7	0	1	1				
HM	95	R	35			25	35	39	33	4
	95	C	30	30	15	30				
HM	80	R	16			10	13	18	18	0
	80	C	17	8	8	10				
HM	50	R	8			4	1	0	4	0
	50	C	4	3	2	3				

Abbreviations: MCVP=minimum convex polygon; MCCP=minimum concave polygon;
HM=harmonic mean

R=red wolves, C=coyotes

comp=comprehensive, G=gestation (16 Mar - 30 Apr), PR=pup-raising (1 May - 31 Jul), D=dispersal (1 Aug - 31 Dec), PF=pair-formation (1 Jan - 15 Mar).

^aFor polygon ranges, percentage of points used from sample; for harmonic mean, probability isopleth.

The 3 analyses of simple movements generally supported a single conclusion. All 3 analyses matched the expectation of decreasing likelihood of interaction among the comparisons. The index of spatial overlap returned values between 0.19 - 0.97 (Table 6 A.). The 2 hypothesis tests appeared to return different conclusions on whether comparison 3 (CAM-2 and CJM-7) represented probable interaction. The test of distribution classified the 2 samples as likely to originate from a common distribution (Table 6 B.), whereas the test of inter-animal distance indicated these coyotes maintained greater separation than would be expected at random (Table 6 C.).

Assessment of project procedure

The flow-chart illustrating observed reintroduction procedures closely corresponded to the structure of procedures established in the project proposal (Fig. 6). Only the elements originally identified as "release strategy" and "recapture techniques and procedures" were modified because 1) the events and activities related to the soft-release strategy were all entailed by the acclimation period, so "acclimation period" was added to the description; 2) recapture was only one category of events and activities that followed release; therefore this element was relabeled "monitoring." Elaboration on the results under each element of the flow-chart follows.

Table 6. Results of analyses of simple movements among study animals during pilot-reintroduction of red wolves in GSMNP. Prefixes to i.d. numbers: R=red wolf, C=coyote / A=adult, J=juvenile / M=male, F=female.

A. Quantification of spatial overlap.

Comparison and identification codes	Value of Powell-Pianka index (Powell 1987)
1: RJF-467/RJF-468	0.97
2: RAM-219/RAF-303	0.97
3: CAM-3/CJM-7	0.7
4: RAM-219/CAM-3	0.38
5: RJF-467/CJM-7	0.19

B. Multiple-response permutation procedure.

Comparison and identification codes	Observed δ	Expected δ	Pr ($\leq \delta$)	Physical interaction is...
1: RJF-467/RJF-468	1.548	1.5475	0.37	likely
2: RAM-219/RAF-303	1.572	1.574	0.25	likely
3: CAM-3/CJM-7	1.556	1.553	0.45	likely
4: RAM-219/CAM-3	1.418	1.578	<0.001	unlikely
5: RJF-467/CJM-7	1.486	1.6	<0.001	unlikely

C. Test of inter-animal distance.

Comparison and identification codes	Mean inter-animal distance (m)		Pr ($> Z $)	Observed distance is...
	obs.	random		
1: RJF-467/RJF-468	559.6	2176.8	<0.001	closer
2: RAM-219/RAF-303	508.6	2664.3	<0.001	closer
3: CAM-3/CJM-7	4233.2	2260.5	0.16	questionable
4: RAM-219/CAM-3	6061.5	2656.9	0.002	farther
5: RJF-467/CJM-7	3144.4	2518.3	0.005	farther

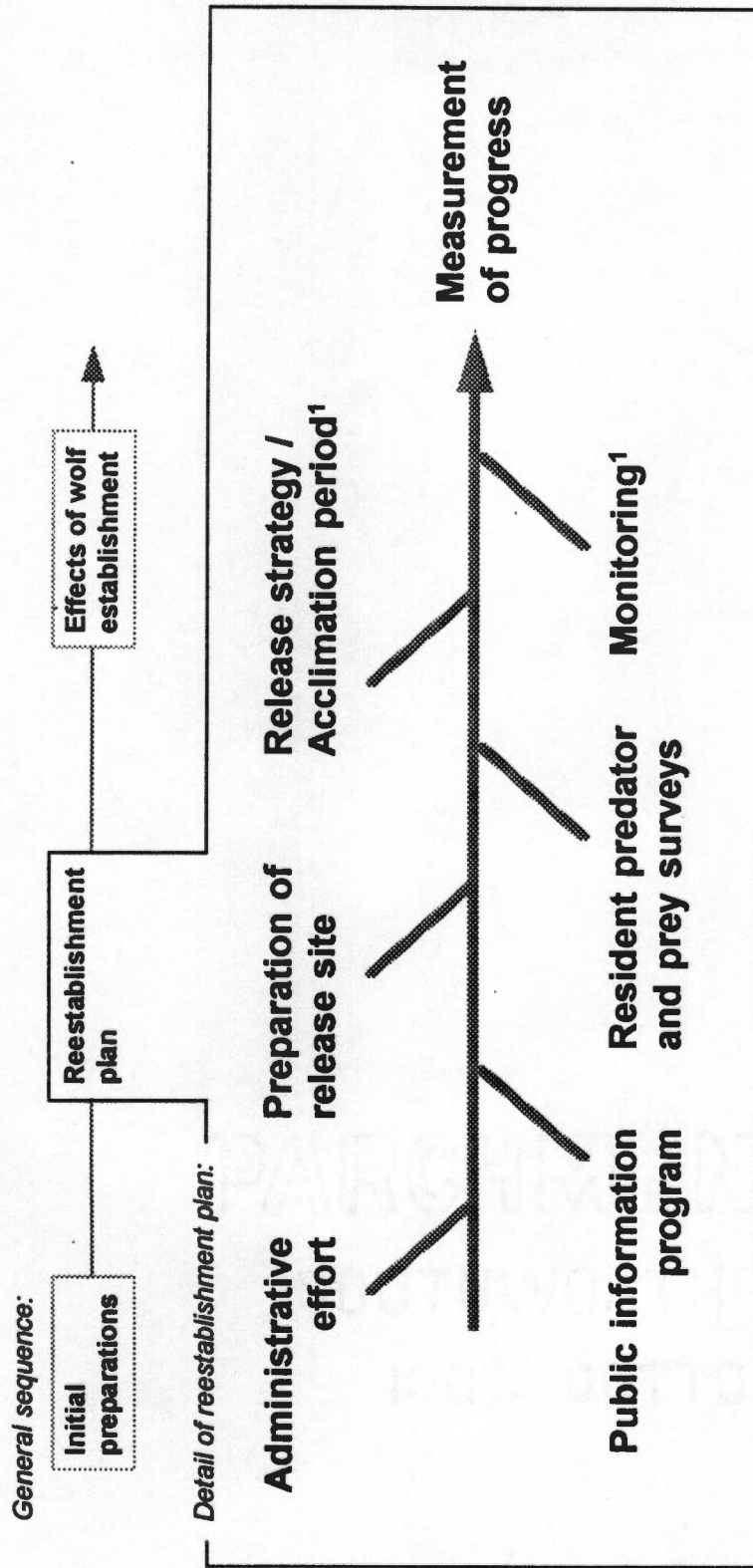


Figure 6. Flow-chart of project procedures observed during pilot-reintroduction of red wolves in GSMNP, 1991-1992, indicating the general sequence and the details within the reestablishment plan. ¹These elements were observed to represent events and activities other than described in the planning documents and therefore were relabeled.

The first general element, "Initial preparations" was planned to consist of a public information program and public meetings. The public information program was developed in cooperation between GSMNP staff and RWRP and included a glossy brochure and a professionally-published newsletter produced through the Point Defiance Zoo and Aquarium (where the captive breeding program is based). A contract was arranged with a local professional photographer to provide photographs for informational material. In addition, project personnel responded to solicitations for interviews and worked closely with a local television station that produced a half-hour, prime-time documentary on the project.

The other phase of this element, the public meetings, was not carried out. Instead, a single group was formed—the Red Wolf Communication Committee—consisting of land managers from adjacent public and private lands, and representatives from a farming interest group, conservation interest group, sportsmen's interest group, and the state wildlife management agencies of North Carolina and Tennessee. This committee was convened to discuss the project and air concerns prior to the initial release on 2 Oct 91 and again to review the pilot-reintroduction on 5 Jun 92 (B. Miller, NPS/GSMNP, pers. comm.).

The second general element of the procedures, "Reestablishment plan" was the most developed, comprising a sub-sequence of events. As noted previously, the administrative efforts were complicated by a delay in the processing of paperwork regarding the experimental / non-essential designation of the study

animals. The public information program during the reestablishment phase continued with involvement by the professional photographer and the television station, and field personnel continued to grant interviews.

Under "preparation of release site," construction of acclimation pens took place as scheduled, but the development and testing of the radio-tracking system consisted of obtaining the dart-collar system, learning to use the equipment, and troubleshooting malfunctions. No effort was made by RWRP personnel to determine the accuracy of the location estimates produced by the radio-tracking system.

The "resident prey and predator surveys" consisted of Crawford's (1992) study of coyotes prior to the pilot-reintroduction phase of the project. No prey surveys were conducted. Crawford (1992) concludes that howl-surveys may prove useful as a means of indexing abundance of coyotes, which is estimated in the range 1 coyote / 12.9 km² to 1 coyote / 39.7 km². The movements of coyotes were marked by large dispersals, prompting the conclusion that the collared animals had not established stable movement patterns.

The "release strategy" required conducting an acclimation period, which was incorporated into the label of this element. Some details about the acclimation process were observed that were not reported in the planning documents. Events and activities included feeding, handling, and viewing (Table 7). Other than the feeding protocol (once approximately every 2 days), no firm

Table 7. Observed events and activities within the modified elements of the flow-chart of procedures for red wolf reintroduction in GSMNP (originally described in planning documents).

A.	Release strategy / Acclimation period (originally "release strategy").
1.	feeding scheduled entry to pen, approximately every other day.
2.	handling veterinary inspections, treatment of pups for staph infection, implantation of radio-transmitters.
3.	viewing visual inspection of health.
B.	Monitoring (originally "recapture techniques and procedures").
1.	behavioral problems tame behavior (i.e., non-avoidance of humans or human activity), depredation.
2.	manipulation/hazing removal of livestock carcasses, firing of ballistic and pyro-technic scare devices, vocal and physical scare tactics, administration of medicine in meat baits.
3.	handling capture, both inadvertent and intentional for collar maintenance or to control behavioral problems.
4.	supplemental feeding as scheduled by soft-release procedure, repeated for re-releases, and for manipulating behavior.
5.	equipment failure dart-collar malfunction.
6.	agonistic encounters with coyotes evidence such as growling and other vocalizations, pursuit, or tufts of hair accompanying location data suggesting an encounter.

criteria guided the access of humans to the pen area. The area was posted to exclude park visitors, but project personnel entered the area as deemed necessary to conduct various duties in maintaining the captive animals. No precautions were taken to reduce the probability of the captive animals associating project personnel with food. This precaution has not been a concern at the ARNWR reintroduction project (M. K. Phillips, USFWS/RWRP, pers. comm.), and the handling procedure is believed by the captive-breeding curator to maintain the animals' natural aversion to humans (R. Smith, Point Defiance Zoo, Tacoma, WA, pers. comm.). This element of the flow-chart was affected by the administrative delay in obtaining legal designating for the study animals as described previously.

The "recapture techniques and procedures" element was relabelled as "monitoring" because it was observed to comprise 6 events and activities not limited to recapture (Table 7). Nevertheless, a significant event in this stage of the project was the necessary recapture and subsequent withdrawal of RAM-219 from the project. It should be noted also that some events and activities entered in the daily log during the monitoring phase of the project were entailed by previous stages in the flow-chart (Table 8); only events and activities under the monitoring category "status and manipulation of free-ranging red wolves" could be tabulated.

The relative importance of the events and actions, based on frequency of notation in the activity log, is displayed in the form of a Pareto chart (Fig. 7).

Table 8. Categories of events and activities recorded in daily log of the pilot-reintroduction of red wolves in GSMNP.

Administrative efforts

inter-agency administration/assistance
project administration
project development /expansion

Public information program

interviews
presentations

Acclimation period / Release strategy

captive breeding

Monitoring

coyote interactions
depredation
feral-dog interactions
human interactions
livestock interactions
movements and food habits
status and manipulation of free-ranging red wolves

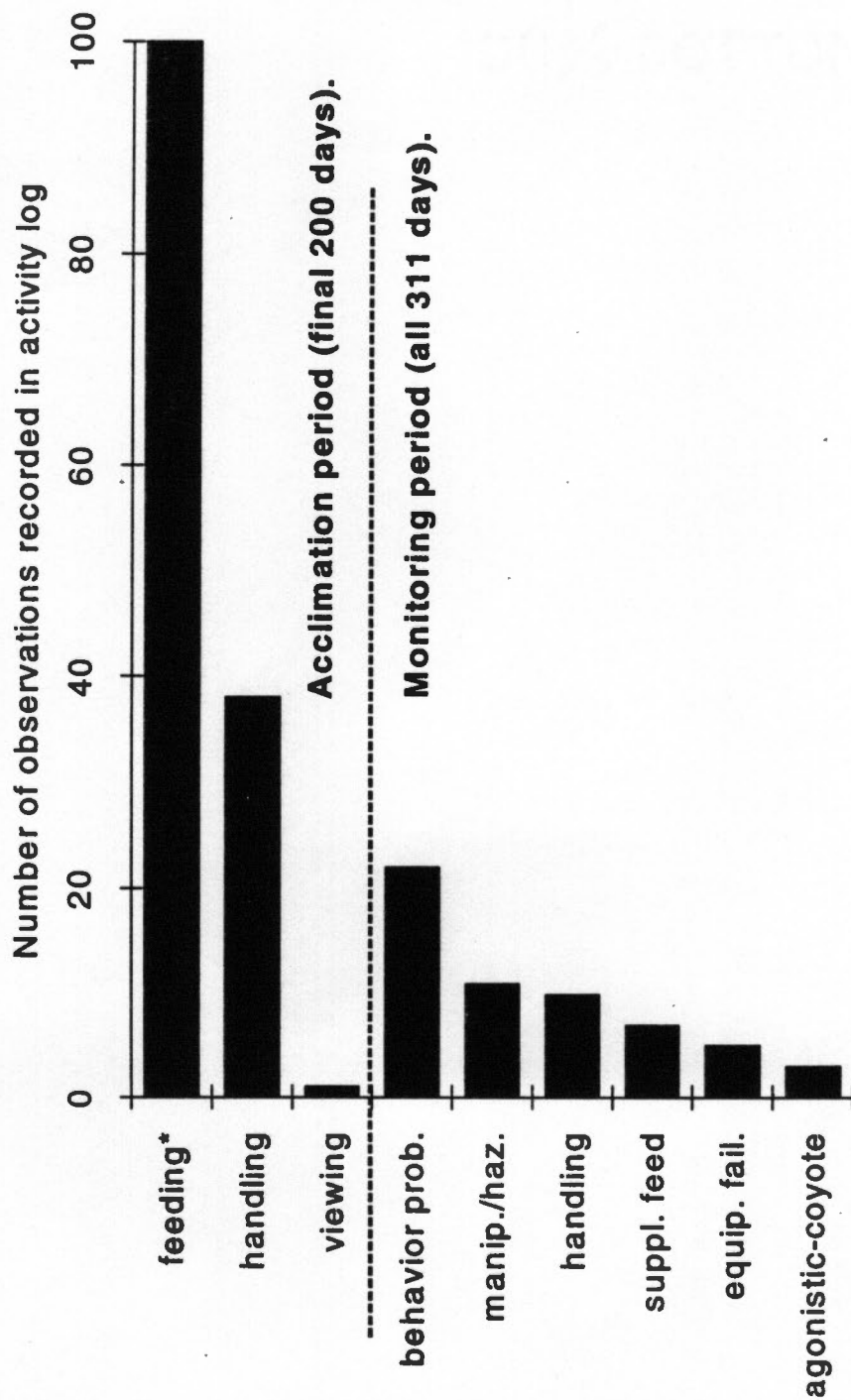


Figure 7. Pareto-diagram analysis of data comparing events and activities recorded in daily activity log of the pilot-reintroduction of red wolves in GSMNP within the "status and manipulation category" of observations. *Feeding events were estimated at 1 per 2 days.

This analysis suggested that behavior problems occupied more time and activity from the field personnel than did equipment failure.

V. DISCUSSION

This study suggested that conducting research concurrently with a management action may require modified information-gathering techniques. The results of the investigation into the spatial use of coyotes and red wolves illustrated several problems that were encountered in the attempt to combine management and research. The assessment of project procedures illustrated a non-traditional approach to gathering information that might facilitate concurrent research and management in the future.

Assessment of interaction

The assessment of physical interactions between reintroduced red wolves and resident coyotes was only 1 objective of research conducted while the RWRP sought the management goal of determining whether permanent reintroduction is feasible. The combination of this management goal with the research objective of studying physical interaction led to difficulties that impeded controlled scientific observation.

The difficulties encountered in approaching the question of interaction by traditional methods of wildlife science raised the possibility that alternative methods of gathering information are better suited for the monitoring aspect of project procedures. The reintroduction showed that red wolves could be released and controlled sufficiently to satisfy the Red Wolf Communication Committee.

Furthermore, the movements of the both red wolves and coyotes showed a general affinity for the coves within the study area, which both species used, sometimes in relatively close proximity although some evidence of agonistic behavior was observed.

The methods proposed for this study were typical of observational wildlife science, but the results were compromised by the conditions prevailing over the observations. Induction was the method relied upon, which is the declaration of a general scientific fact on the strength of repeated observations, and which is a common form of wildlife science (Romesburg 1981). For example, by induction, the measurement of spatial use of red wolves and coyotes can support a declaration of aversion or affiliation between the 2 species. The reliability of induction is based on the measurement system, which includes the conditions under which measurements are taken. The problems this investigation identified in the measurement system proposed for monitoring the reintroduction are based on differing purposes and needs for information between the management and research dimensions of the project. The problems between these 2 dimensions were evident in the planning, conduct, and results of the monitoring.

The planned objectives for research took lower priority than the management goal of determining whether reintroduction of red wolves is feasible was of primary importance. The selection of the study area was based on the probability of a successful reintroduction, not the feasibility of an interaction

study. As a result, the study area presented difficulties in attempts to monitor coyotes (i.e., primarily the restrictions on trapping techniques, also the difficulties in radio-telemetry posed by the terrain and the high visitor traffic).

Operations of the project also posed difficulties to employing traditional data-collection. Attempts to control the movements of the red wolves were part of the strategy for achieving a "cooperative relationship with involved agencies and local citizens" (C. Lucash, USFWS/RWRP, unpubl. rept.). This required unplanned manipulation of the study animals and precluded observations of the ability of red wolves to travel. Because depredation could jeopardize relations between the RWRP and private landowners, a general policy was followed to retrieve study animals that left public property and to curtail their movements within the park. Similarly, regarding interaction, the delay in releasing red wolves and the priority of knowing the location of red wolves with respect to the park boundary and the cattle in Cades Cove, reduced the effort toward observing coyotes. Furthermore, the field personnel became persuaded that interactions between red wolves and cattle presented a greater danger of undesirable behavior, and therefore further detracted attention from coyotes. As a result, the conclusion regarding interaction between red wolves and coyotes is based on weak data and the impression among field personnel that undesirable (i.e., non-agonistic) interactions did not occur between reintroduced red wolves and resident coyotes.

The samples of locations estimates reflect the emphasis of the project. Sample sizes of location estimates were heavily skewed toward red wolves because more time and trackers were assigned to these animals to identify sudden dispersals. Tracking was limited also by requirements of other responsibilities of the project, such as maintaining captive-breeding facilities and administrative duties, and also by the limitations on field-skills among volunteers. The major limitation on the sample of simultaneous observations of red wolves and coyotes was the unforeseen delay in obtaining legal authority to release the red wolves.

The differing purposes between management and research aspects of the project created differing needs for information. Programs operate on strategic and operational levels of scale: strategy entails decisions about developing and planning projects within the overall program goal, whereas operation comprises the daily decisions of executing a particular project (Starling 1988). The research aspect of this investigation served strategic purposes and required data to support strategic decisions, but the management aspect served operational purposes and required data supporting operations (i.e., immediate action). The result of this was evident in the manipulation and hazing of red wolves.

Strategic decisions use existing information to support plans. Spatial analyses are a means of establishing information for later use in planning. For example, based on this project, the RWRP might expect that reintroductions in similar habitat using a similar acclimation process will result in confined

movements centered near the acclimation pens and requiring occasional manipulation of red wolves for equipment maintenance, retrieval, or aversive behavioral conditioning. Based on these results, the RWRP can plan future reintroductions around the need to understand the causes of problems such as tame behavior and depredation.

Other uses of research findings also are strategic and, in addition, require different data. The methods of risk- and decision-analysis, which have been applied to endangered species projects (Maguire 1991, Maguire et al. 1987) require a base of data from which to identify possible outcomes and to estimate the probabilities of each. For example, a measure of dispersal from spatial analysis, such as minimum-area polygon home range, could be related to categorical data such as method of release, composition of release group, length of acclimation. These methods may be worthwhile to the program, but would require several releases in order to develop probabilistic relationships. Because reintroduction allows managers to manipulate and better describe the factors potentially affecting each study animal, these data can be related to more general descriptions of the result (i.e., movement behavior). The monitoring process employed here emphasized intensive measurement of the result by spatial analysis, which drew attention away from measurement of the possible effects (i.e., the acclimation process, handling and baiting events). Data on both are necessary to relate management actions to results and thereby measure progress.

The intensive data-collection on spatial use highlighted another difference in needs of information. Whereas the point estimates of location were obtainable by the field team, they were of little value in daily operations. The activity log demonstrated that the desired information primarily was the general whereabouts of the red wolves (i.e., inside or outside GSMNP), with additional interest in the proximity, but not location of, the coyotes. The general locations of the red wolves were used in the consideration of depredation claims and reported sightings outside GSMNP, and triangulation data were collected for future study. Therefore, radio-telemetry partially served both purposes of management and research. The purposes of management overlooked were the value of describing the relationship between exposure of red wolves to project personnel and the demonstration of tame behavior and depredation. The research purpose overlooked was simultaneous location estimates for red wolves and coyotes.

The comparison of these findings with other studies illustrate 2 problems. First, and perhaps most obvious, inferences are weak about the relative spatial use of these 2 species. In general, home ranges were larger for red wolves compared to coyotes, and the analyses of simple movements confirmed expectations that the red wolves would travel as a group and that coyotes would use separate areas from the red wolves and other coyotes in the study. Second, the reintroduction procedure and associated difficulties resembles other reintroduction projects.

The analysis of interaction was limited by uneven sample sizes and the large time-window used to encompass paired observations. The data support the possibility that these animals maintained separate ranges and avoided one another, but both the weaknesses of the data set and the alternative explanations for the observations qualify this observation. Either the suspected canid hierarchy along the gradient of body size or the difference in intra-specific social relationships between the 2 species could explain the findings of this study. The condition of an intact family-group alone could explain any partitioning of space. For example, the integrity of the family group even after the recapture of the adult male could be explained by factors alternative to some barrier to interaction between red wolves and coyotes.

Although many location estimates of red wolves were recorded, the data on handling, baiting, and tame behavior were collected opportunistically and could not be related to movements and other behaviors to study handling effects. With some modifications of the data-collection scheme, comparisons between spatial use of these red wolves and other red wolves handled by the RWRP could be studied for the effect of the acclimation and reintroduction procedure.

The home ranges of the red wolves in this study resemble those of other red wolves. The minimum convex polygon home-range sizes from this study (62-85 km², excluding RAM-219) fall below the range of estimates from ARNWR of 90-130 km² (M. K. Phillips, USFWS/RWRP, pers. comm.). Estimates calculated

prior to the captive breeding program are: 44 km² (Shaw 1975); ♀ = 65-78 km², ♂ = 117 km² (Carley 1975); 65-130 km² (Riley and McBride 1972). The fact that the juvenile red wolves did not disperse is not unusual. Dispersing juveniles at ARNWR ranged in age from 7-22 mos. (unpubl. data).

The tracking data on coyotes adds information on the dynamics of the population in this area to that reported from the earlier phase of this study (Crawford 1992). The comparison of coyote ranges with those documented by Crawford (1992) suggest that these animals established stable home-ranges during this second phase of the study (Table 9). In most cases, the seasonal home-range during Phase II was smaller. The pattern could be explained by the possibility that the coyotes in Cades Cove were isolated when originally captured, leaving available habitat outside GSMNP easily accessible to dispersing juveniles.

Whereas the data weakly support the analyses, the analytical methods fit well within the needs of spatial analyses identified by White and Garrott (1990) and Laundré and Keller (1984). Having reviewed telemetry studies, these authors argue that measurements such as home range must be compared to other measures in order to better advance understanding about movement behavior. Other factors are social, physiological, and seasonal. For example, the use of the Pianka-Powell index of overlap (Powell 1987) could be employed in research-driven projects and related under experimental control to characteristics such as those suggested by

Table 9. Comparison of seasonal home ranges (km²) of coyotes tracked in GSMNP during 1990 (Crawford 1992) and 1991 (this study). Prefixes to i.d. numbers: C=coyote / A=adult / M=male. All were 1 yr old in 1990 (Crawford 1992).

Animal i.d.	Gestation		Pup-rearing		Dispersal		Composite	
	'90	'91	'90	'91	'90	'91	'90	'91
CAM-2	13	37	56	12	52	28	112	96
CAM-3	2	4	10	8	15	11	25	19
CAM-4	24	8	152	18	72	21	231	30

Laundré and Keller (1984) (e.g., vegetation, physiographic features). Furthermore, the hypothesis tests of interaction provide a more explicit consideration of spatial overlap than the graphical methods of Harrison et al. (1989), Sargeant and Allen (1989), Major and Sherburne (1987), Sargeant et al. (1987), and Fuller and Keith (1981).

The difficulties in obtaining better data during the reintroduction resembled the difficulties of other reintroduction and translocation studies. Whereas grey wolf studies have succeeded in documenting movements with traditional techniques (Fritts and Mech 1984, Henshaw et al. 1979, Weise et al. 1975), none of these studies attempted simultaneous reintroduction and study of interaction. The examples of projects with birds and other mammalian species indicate that record keeping often lags among the multiple responsibilities of conducting the projects (Chivers 1991, Ounsted 1991).

Assessment of project procedure

The assessment of procedures suggested that the RWRP has developed a standard protocol for reintroduction projects, and that further specification of the procedures as indicated in the flow-chart may identify areas where adjustments can be implemented to improve the process. At the level of general procedures (i.e., initial preparations, reestablishment plan, effect of wolf reestablishment), the current procedures for initial preparations apparently performed well in this

reintroduction as they did at ARNWR. The reestablishment plan also succeeded because the result of the 5 Jun 92 meeting of the Red Wolf Communication Committee was a decision to proceed with permanent reintroduction. The data that were collected on the sub-procedures, however, suggested areas for possible improvement that are discussed below. The final general procedure, determining the effect of wolf reestablishment has not yet been reached as no group of free-ranging wolves can yet be declared a reestablished population.

General discussion of statistical process control. To interpret the tally data on activities and events within the reestablishment plan procedure, a general discussion of the analytical approach is necessary. Flow-charts require some measure of progress as an empirical standard against which to compare modifications in the procedures. The choice of this measure necessitates the definition of the scale at which the process is to be measured (U. T. 1992), and must be related to the events and activities represented throughout the process. For example, a measure of progress at the strategic level could be the number of pilot-reintroductions that become permanent reintroductions. This was informally used during the 1980s as the proposed project at Land Between the Lakes failed and the lack of a public information program was identified as the cause. Measuring the process at this level, however, is not sufficient because more specific information about the process is available.

An example of a measure at a more useful scale could be a number similar to trap-nights or man-hours, for example, wolf-nights of free-ranging status. Wolf-nights could be measured per day, week, or month. This measure would allow comparisons between the effect of events and activities among elements of the flow-chart. A cursory, retrospective application of this measure to the data from this project shows that administrative matters regarding experimental / non-essential designation cost the project approximately 4 months or $(123 \text{ nights} \cdot 4 \text{ wolves}) = 492 \text{ wolf-nights}$. Also, the ability for red wolves to associate with people during acclimation might have been the cause of behavioral problems requiring the capturing and holding of animals. No data were specifically recorded on duration of holding recaptured study animals, but the wolf-nights it cost clearly fall short of 492.

The choice of the measure of progress must have significance toward the overall goal of the project. Wolf-nights may be generally related to progress toward what could be termed a reestablished population, but it might also be found to build the confidence of the land managers on the Red Wolf Communication Committee and motivate their willingness to engage in a new reintroduction project. Establishing small numbers of wolf-nights in several sites may be a more important step toward recovery than raising the number of wolf-nights in a single reintroduction site. Because the meaning of such a number is hard to determine,

the involvement of the entire field team and their collective, detailed knowledge of constraints and opportunities at the field level is necessary.

Statistical process control in this study. Comparing this general discussion of the statistical process control approach to this study shows that only a primitive application was made in this study. First, the tallies of events and activities is not a measure of results as wolf-nights would have been, but rather is a measure input inasmuch as the log entries reflect the field team's allocation of time and effort. Second, a measure of input is difficult to relate to progress, although some qualitative ideal can be considered such as: "more progress is being made as less time and effort are spent responding to problems."

These data do not support an ideal analysis but they are of value to establish a starting point in the use of the statistical process control approach. The data tabulated fall in the flow-chart element of monitoring and show that considerable effort was required in dealing with behavioral problems. Whereas even the most extreme problem of the necessary withdrawal of RAM-219 from the project did not thwart the project, the difficulties were reported by the news media and also were discussed in the 5 Jun 92 meeting of the Red Wolf Communication Committee, exerting an unmeasured effect on the willingness of managers of adjacent lands to host future reintroduction projects.

Despite this limitation of the measurement system, the results suggest that more time was spent on behavioral problems in the red wolves than is desirable.

Searching for the root cause of this among the previous stages of the flow-chart, led to a likely explanation in the acclimation / release-strategy element. The feeding procedure was an opportunity for the captive animals to associate project personnel with food, and anecdotal reports were available from the volunteer caretakers that some behavioral problems were observed prior to release. The fact that these behavioral problems have not arisen at ARNWR under similar acclimation procedures suggests that other factors could contribute to this problem.

At this point in the flow-chart analysis, the usefulness of this statistical process control approach is made clear, but the usefulness can be demonstrated only with further data collection. The field team would at this point consider the possible causes of the behavioral problems and propose a remediation such as feeding captive red wolves from behind a blind to reduce interaction between project personnel and study animals. The remediation would be executed in a subsequent release, and data would be collected to document any change. It is important to note that this quasi-experimental approach is subject to erroneous conclusions based on false correlations. The trade-off that could justify this risk is that these methods provide a systematic means of monitoring the project that focuses attention on problems in priority of measurable criteria. To employ this "quick-and-dirty" approach seems preferable to failing to implement fully a more tightly-controlled monitoring procedure such as an interaction study. In addition

to providing little useful information, the rigid, preconceived design may limit attention to what bears out to be an insignificant feature of the project.

Statistical process control in future studies. Just as a general discussion of this analytical approach was necessary prior to the discussion of the findings, so it is necessary to introduce the discussion of implications for this approach in future research. The application of the approach in this study was limited by using available data rather than developing a more pertinent measurement system. Below, I have illustrated 4 tools of the statistical process control approach to prompt discussion of possible applications for the future. The tools are the check-sheet, concentration diagram, np-chart, and x-bar chart.

The check-sheet is a data-collection form designed to combine data-collection and analysis. An example check-sheet is presented to replicate the Pareto analysis based on the data of this study (Fig. 8). If the results of this Pareto analysis motivated new acclimation procedures to minimize the association between humans and food (such as feeding from a blind), then a check-sheet for the monitoring of the red wolves fed this way might display improvement (Fig. 9).

The concentration diagram is another tool combining data collection and analysis which is a graphic form designed to resemble the subject under study. For example, if obtaining location-estimates for traditional spatial analysis is determined to be impractical, but some measure of relative location of red wolves

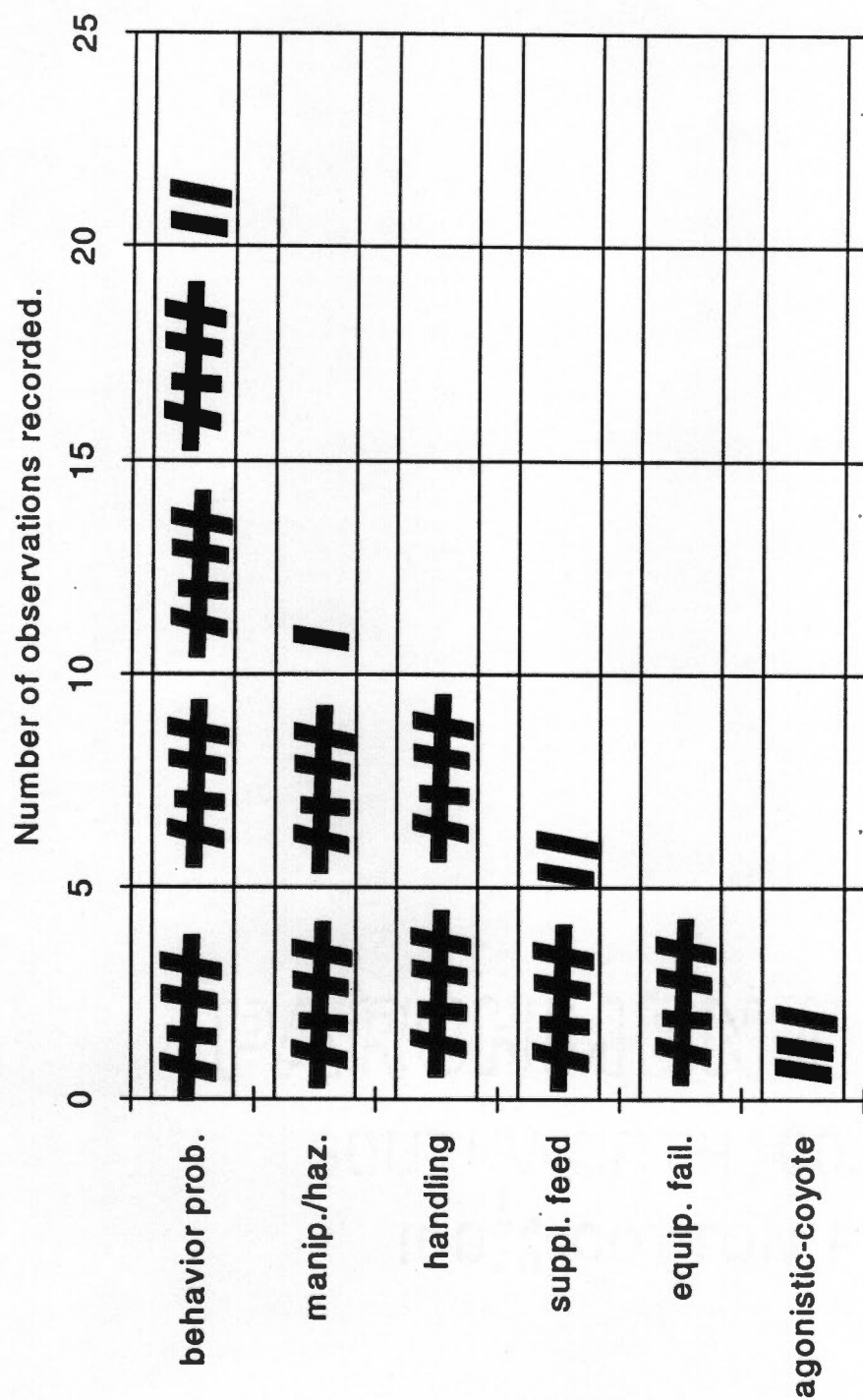


Figure 8. Data on events and activities recorded in daily log of the pilot-reintroduction of red wolves in GSMNP displayed in a check-sheet that could be used in future monitoring.

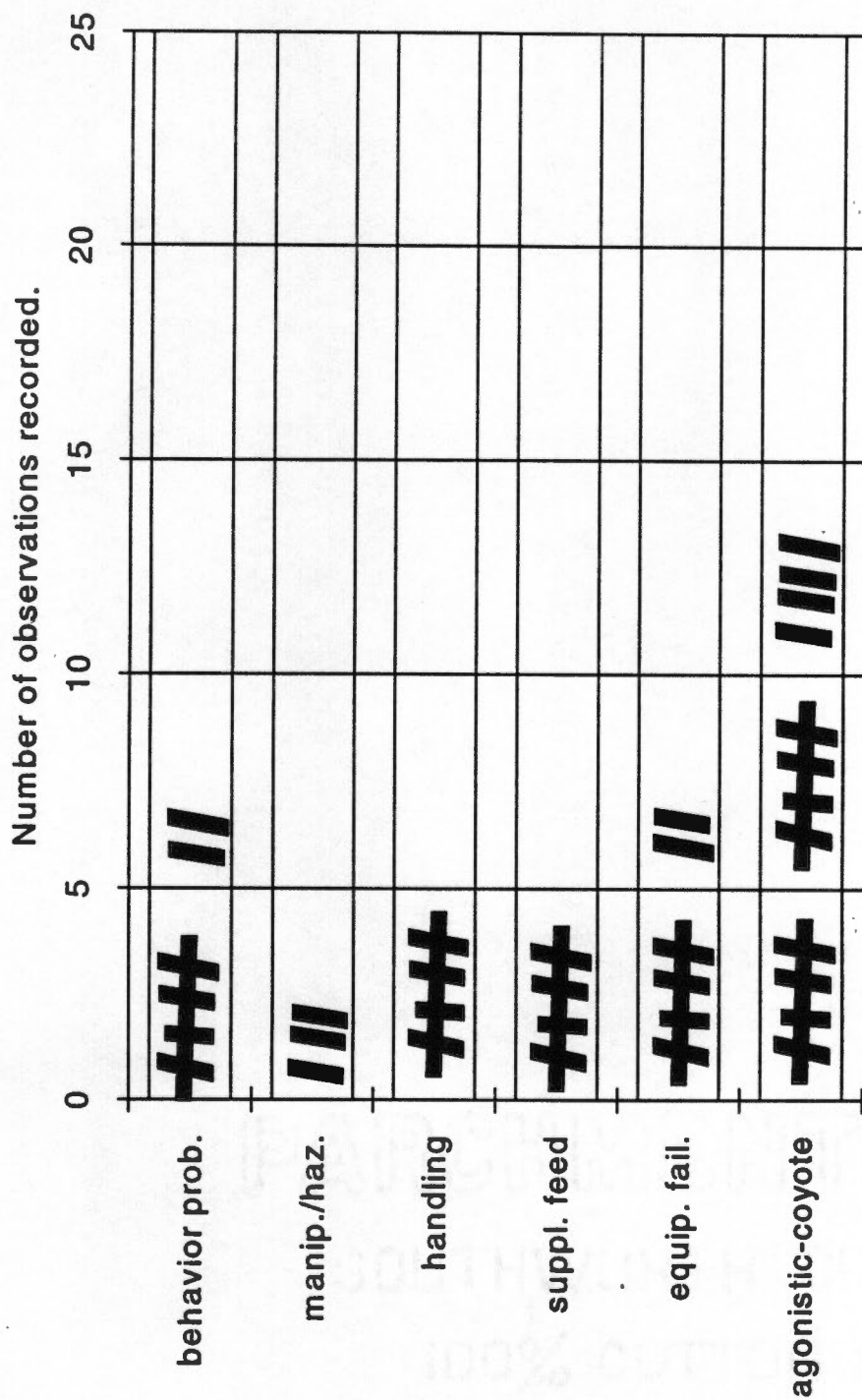


Figure 9. Hypothetical data displayed in check-sheet to illustrate analysis of improvement.

and coyotes is desired, a concentration diagram could provide a useful alternative. Using the features of Cades Cove as a convenient way to categorize location, a concentration diagram for recording a day-long observation period is presented (Fig. 10). Field personnel would carry a clean diagram each day. This would permit a systematic, albeit general, means of observing spatial use without detracting time or effort away from other project duties. When a stack of diagrams has accumulated, project personnel can review them to determine the general pattern of relative movements. Interesting results could be followed up with more rigorous methods.

The control chart provides a time-series analysis of progress toward a goal; the np- and x-bar- charts are types of control charts. If the measurement of progress in the procedure is based on attribute data (e.g., occurrence or absence per observation or tally of occurrence per observation), then an np-chart could be used. If the measure is based on variable data (e.g., distance measurements), then an x-bar-chart could be used.

For example, the problem of depredation on cattle could be approached in at least 2 ways. The easiest measure of potential for red wolves to kill livestock may be the number of occurrences of red wolves in the same pasture with the herd. This measure could be assumed to reflect the hunting behavior of the red wolves as they might be assessing the herd for accessible calves (Alcock 1984).

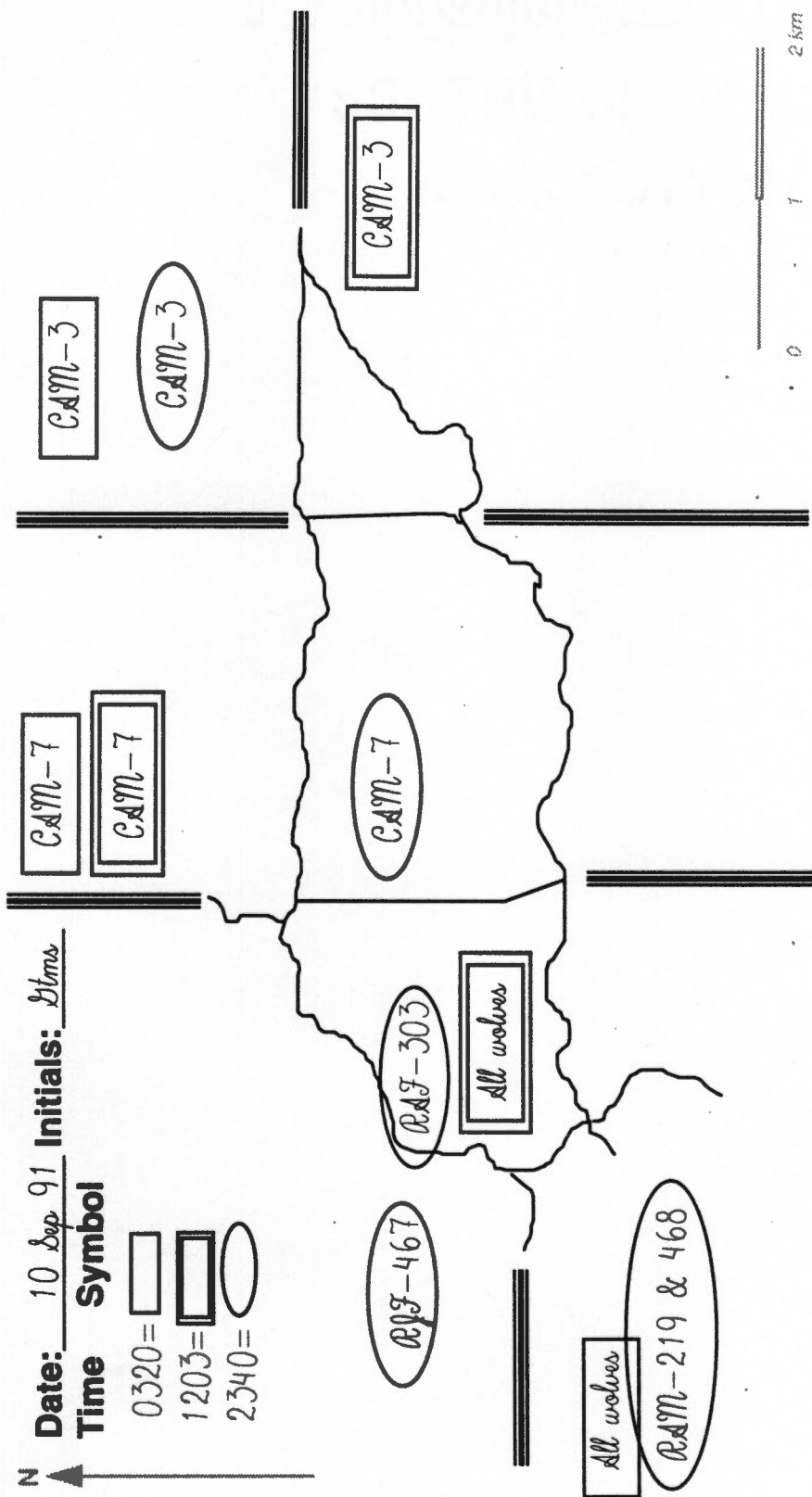


Figure 10. Hypothetical data in an example concentration diagram based on the road-system in Cades Cove, GSMNP, illustrating how the area could be divided into sectors for recording approximate position of red wolves and coyotes during a day of monitoring. Notations in script represent entries by observer.

The field team could use the sampling schedule for monitoring the red wolves to tabulate on a chosen scale of time the occurrences of red wolves in pastures simultaneously with cows. These numbers could be plotted in an "np-chart" to assess the variation in observed visits to pastures (Fig. 11). The determination that the data are "in control" means that only random influences are acting. If the data are "out of control", the investigation proceeds toward finding factors that affect visits to pastures. Once identified, these factors could be controlled to establish a predictable pattern.

A more involved use of a control chart could employ the estimation of distance between the telemetry location-estimate of the red wolf and a point-estimate of the center of the herd. This could be plotted on an "x-bar-chart." The uses of the x-bar-chart include assessing change in the measure following an action taken to affect its magnitude (Fig. 12). For example, if yarding pregnant cows during the calving season increases the energy cost to red wolves of taking a calf, then the red wolves may shift their movements toward other prey sources and the average distance from the herd may increase. If the higher average distance remains above the centerline of the chart for ≥ 7 sampling opportunities, the rule-of-7 is used to declare that the desired result has been achieved.

In practice, the application of these techniques requires the combination of the experience of field personnel with the expertise of researchers trained in statistics. Hahn (1984) recommends the involvement of statisticians early in

Measurements to assess variation:

number of runs = 11 (individual points + 3 multiple-point runs marked by boxes)

number of points above/below centerline (smaller value assigned to s , right of chart)

Assessment (Swed and Eisenhart 1943):

critical value for number of runs=4 (derived from a table for values of s and r)

if observed number of runs exceeds the critical value, the data are "in control"

if observed number of runs is equal or less than the critical value, the data are "out of control", meaning some factor is affecting the variation

CONCLUSION: $11 > 4$, "in control"

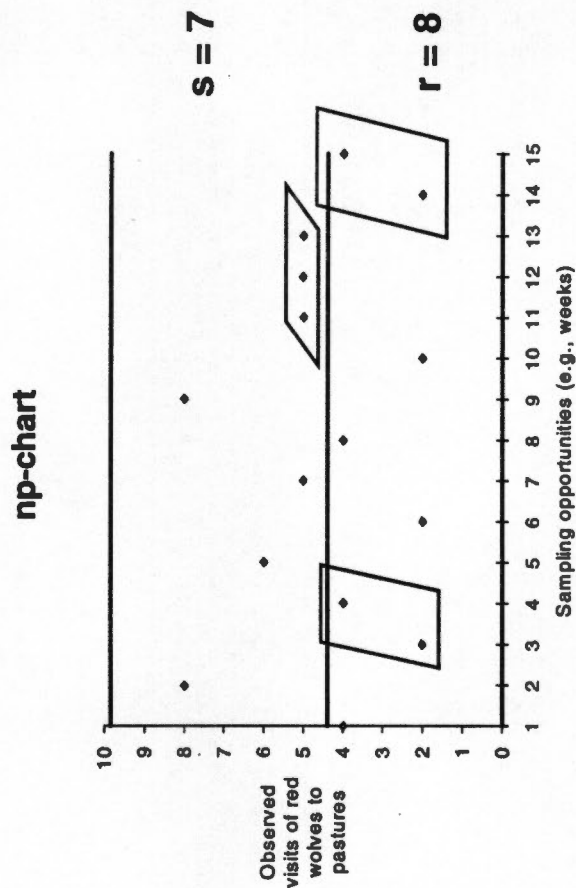


Figure 11. Hypothetical data in a control chart for assessing variation in visits of red wolves to pastures holding cattle.

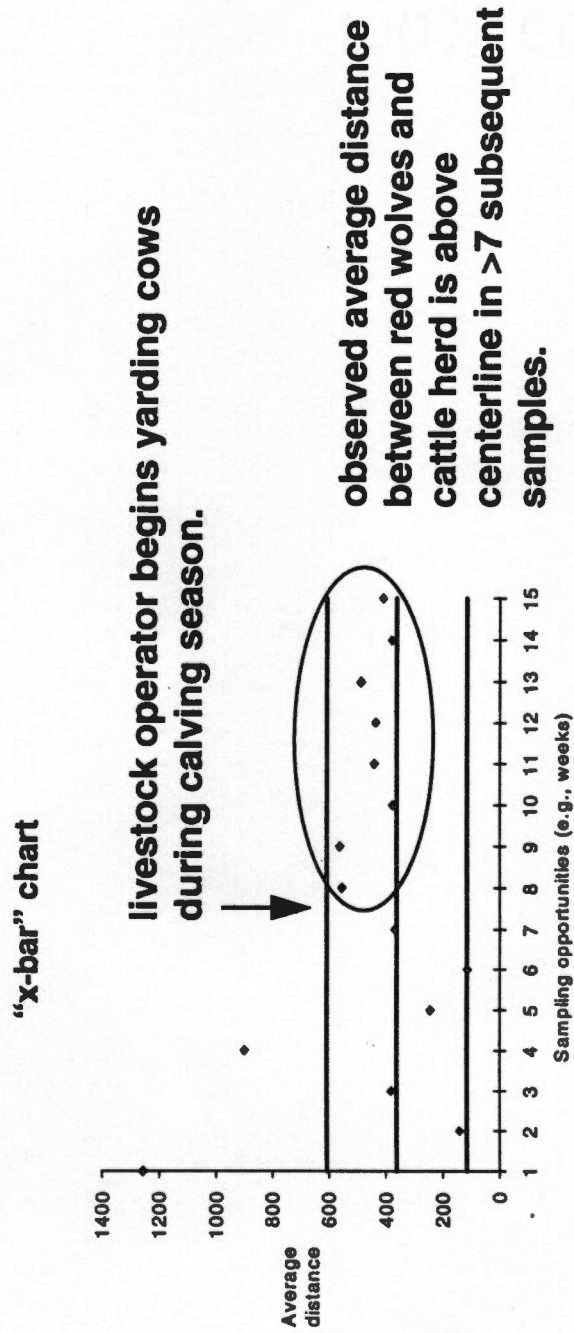


Figure 12. Hypothetical data in a control chart illustrating change in average distance between red wolves and cattle herds by "rule-of-7".

project development, which may be easier to accomplish when the field personnel can see more immediately the purpose of data collection. Furthermore, effort must be made to constrain the choice of measurements to quantities directly translatable into demonstrations of progress. These numbers then become evidence that the RWRP could use to support its attempts to find new reintroduction sites.

Conclusion

The primary implication of this study was that future reintroduction projects that include research objectives should improve the reconciliation between the purposes and needs for information between research and management goals. This investigation showed concurrent management and research was not impossible, but that the usefulness of information gathered in each could be improved. The strategic goal of the RWRP to satisfy opponents of reintroduction with the plans to attempt to establish free-ranging red wolves in a new area was achieved and succeeded in providing some information—though limited in scientific quality—about interactions with coyotes. Improvement in the collection and analysis of data in a joint management-research project may be possible with techniques better suited to the combination of purposes, such as the techniques of statistical process control for diagnosing and remediating production problems. Research-management projects can be studied as statistical process control

problems because the need for description and testing must be met without halting production, and because the process is manipulated as improvements are attempted instead of as dictated by experimental design.

The research approach and the statistical process control approach differ in the certainty required to support conclusions in an investigation and the direction of inquiry following each investigation. These 2 paradigms differ in 2 features. One, experiments are held to higher standards of objectivity through careful control and analysis through statistical hypothesis testing, whereas statistical process control is generally based on observational data. Two, the experimental paradigm cycles back to the same general question or problem at which it began, whereas the statistical process control paradigm may direct the subsequent investigation to a different problem.

Published analyses of recovery programs support the idea that flexibility of this kind is necessary for success. The features of effective recovery programs described by Clark et al. (1989) and Clark and Harvey (1988) are based on the same principles proposed for successful statistical process control programs in business administration literature: emphasis on measurable standards of improvement and flexible organizational strategies for attempting improvement (Harari 1993, Milbank 1992, Schaffer and Thomson 1992, Schaffer 1992, Taguchi and Clausing 1992, Beer et al. 1990).

Flexibility in decisionmaking, however, can lead to subjectivity, which increases the potential for misguided decisions. Therefore, I propose that the differences in purposes and needs for information between research and management objectives can be reconciled with the simple analyses used in statistical process control such as Pareto diagrams, check sheets, and control charts.

This approach identifies the need for wildlife managers to emphasize the purpose of monitoring over the use of familiar methodologies for data collection or analysis. On the confusion between investigating a problem and applying familiar methods, Bolles (1988) cautioned:

In the scientific community, one encounters methodologists to whom the ritual of experimentation is all-important and whose thoughts are totally channelled into the routine of statistics. Though that approach is legitimate, and indeed almost the norm, there is the danger that if you ritualize statistics, you may find some of the doors of science closed to you.

LITERATURE CITED

LITERATURE CITED

- Alcock, J. 1984. *Animal Behavior: an evolutionary approach*, 3rd ed.
Sunderland, MA: Sinauer Assoc.
- Beer, M., R. A. Eisenstat, and B. Spector. 1990. Why change programs don't produce change. *Harv. Bus. Rev.* Nov-Dec, p.158-166.
- Bekoff, M., and M. C. Wells. 1986. Social ecology and behavior of coyotes. *Adv. Study Behav.* 16:251-338.
- Berg W. E., and R. A. Chesness. 1978. Ecology of coyotes in northern Minnesota. Pages 229-247 in M. Bekoff, ed., *Coyotes: biology, behavior, and management*. Academic Press, New York, New York.
- Bolles, R. C. 1988. Why you should avoid statistics. *Biol. Psychiatry.* 23:79-85.
- Bowen, W. D. 1982. Home range and spatial organization of coyotes in Jasper National Park, Alberta. *J. Wildl. Manage.* 46:201-216.
- Carbyn, L. N. 1982. Coyote population fluctuations and spatial distribution in relation to wolf territories in Riding Mountain National Park, Manitoba, Canada. *Field-Nat.* 96:176-183.
- * Carley, C. J. 1975. Activities and findings of the Red Wolf Field Recovery Program from late 1973 to July 1, 1975. U.S. Fish and Wildlife Service Report.

_____. 1979. Status summary: the red wolf (*Canis rufus*). Endangered Species Rpt. 7, Albuquerque, NM: U. S. Fish and Wildlife Service.

_____. 1981. Red Wolf experimental translocation summarized. Pages 4-9 in Wild Canid Survival and Research Center Bull. Part I, Winter 1981. Eureka, MO: WCSRC.

Chivers, D. J. 1991. Guidelines for re-introductions: procedures and problems. in J. H. W. Gipps, ed. Beyond Captive Breeding. Symp. Zool. Soc. Lond. 62:89-99.

Clark, T., and A. Harvey. 1988. Implementing endangered species recovery policy: learning as we go? Endangered Species Update 5:35-42.

_____. 1991. Implementing recovery policy: learning as we go? Pages 147-163 in Kohm, K. A., ed. Balancing on the Brink of Extinction. Washington, D.C.: Island Press.

Clark, T. W., R. Crete, and J. Cada. 1989. Designing and managing successful endangered species recovery programs. Env. Manage. 13:159-170.

Clarke, J. N., and D. McCool. 1985. Staking out the terrain: power differentials among natural resource management agencies. State Univ. New York: Albany.

Coleman, J. S. and Jones, A. B. III. 1988. User's guide to TELEM88: Computer analysis system for radio-telemetry data. Dept. of Fisheries and Wildlife,

Virginia Polytechnic Institute and State University, Blacksburg, VA.

Research Series No.1. 49pp.

Crawford, B. A. 1992. Coyotes in Great Smoky Mountains National Park:

evaluation of methods to monitor relative abundance, movement ecology,
and habitat use. M.S. Thesis, University of Tennessee, Knoxville.

Dekker, D. 1983. Denning and foraging habits of red foxes, *Vulpes vulpes*, and
their interaction with coyotes, *Canis latrans*, in central Alberta, 1972-1981.
Can. Field Nat. 97:303-306.

Dixon, K. R., and J. A. Chapman. 1980. Harmonic mean measure of animal
activity areas. Ecology 61:1040-1044.

Dowling, Thomas E., Bruce D. DeMarais, W. L. Minckley, Michael E. Douglas,
and Paul C. Marsh. 1992. Use of genetic characters in conservation
biology. Cons. Biol. 6:7-8.

Dykstra, D. P. 1984. Mathematical Programming for Natural Resource
Management. New York: McGraw-Hill.

Eastman, R. J. 1992. IDRISI User's Guide. Worcester, MA: Clark University.

Fritts, S. H., and W. J. Paul. 1989. Interactions of wolves and dogs in
Minnesota. Wildl. Soc. Bull. 17:121-123.

_____, and L. D. Mech. 1984. Movements of translocated wolves in
Minnesota. J. Wildl. Manage. 48:709-721.

- Fuller, T. K., and L. B. Keith. 1981. Non-overlapping ranges of coyotes and wolves in northeastern Alberta. *J. Mammal* 62:403-405.
- Gilmer, D. S., L. M. Cowardin, R. L. Duval, L. M. Mechlin, C. W. Schaiffer, and V. B. Kuechle. 1983. Procedures for the use of aircraft in wildlife biotelemetry studies. USDI/USFWS Res. Publ. 140. 19p.
- Gipps, J. H. W. 1991. Beyond captive breeding: reintroducing endangered mammals to the wild. *Symposia of the Zoological Society of London*, 62. Clarendon Press: Oxford.
- * Gipson, P. S. 1978. Coyotes and related Canis in the southeastern United States with a comment on Mexican and Central American Canis. Pages 191-208 in M. Bekoff, ed., *Coyotes: biology, behavior, and management*. New York: Academic Press. 384 pp.
- * Gittleman, J. L., and S. L. Pimm. 1991. Crying wolf in North America. *Nature* 351:524-525.
- Hahn, G. J. 1984. Experimental design in the complex world. *Technometrics* 26:19-31.
- Harari, O. 1993. Ten reasons why TQM doesn't work. *Management Review*, Jan. p.33-38.
- Harrison, D. J., J. A. Bissonette, and J. A. Sherburne. 1989. Spatial relationships between coyotes and red foxes in eastern Maine. *J. Wildl. Manage.* 53:181-185.

- Harvey, M. J. and R. W. Barbour. 1965. Home range of *Microtus ochrogaster* as determined by a modified minimum area method. J. Mammal. 46:398-402.
- * Henshaw, R. E., R. Lockwood, R. Shidler, and R.O. Stephenson. 1979. Experimental release of captive wolves. Pages 319-345 in E. Klinghammer, ed. The behavior and ecology of wolves. Garland STPM Press, New York.
- Hill, E. P., P. W. Sumner, and J. B. Wooding. 1987. Human influences on range expansion of coyotes in the southeast. Wildl. Soc. Bull. 15:521-524.
- Janis, I. L. 1971. Groupthink. Psych. Today Nov: 123-132.
- Jennrich, R. I., and F. B. Turner. 1969. Measurement of non-circular home range. J. Theor. Biol. 22:227-237.
- Johnson, D. H., and A. B. Sargeant. 1977. Impact of red fox predation on the sex ratio of prairie mallards. U.S. Fish and Wildl. Serv. Wildl. Res. Rept., 6:1-56.
- King, P. B., and A. Stupka. 1950. The Great Smoky Mountains—their geology and natural history. Sci. Month. 71:31-43.
- Kuhn, Thomas S. 1970. The structure of scientific revolutions, 2nd ed. Chicago: Univ. Chicago Press.
- Laundré, J. W., and B. L. Keller. 1984. Home-range size of coyotes: a critical review. J. Wildl. Manage. 48:127-139.
- Linhart, S. B., and W. B. Robinson. 1972. Some relative carnivore densities in areas under sustained coyote control. J. Mammal 53:880-884.

- *Linzey, A. V., and D. N. Linzey. 1971. Mammals of the Great Smoky Mountains National Park. Knoxville, Tennessee: The University of Tennessee Press.
- Maguire, L. A. 1991. Risk analysis for conservation biologists. *Cons. Biol.* 5:123-125.
- _____, Ulysses S. Seal, and Peter F. Brussard. 1987. Managing critically endangered species: the Sumatran rhino as a case study. Pages 141-158 in M. E. Soule. *Viable populations for conservation*. Cambridge: Cambridge Univ. Press.
- Major, J. T., and J. A. Sherburne. 1987. Interspecific relationships of coyotes, bobcats, and red foxes in western Maine. *J. Wildl. Manage.* 51:606-616.
- *Mech, L. D. 1970. *The wolf: the ecology and behavior of an endangered species*. Nat. Hist. Press, Garden City, NY.
- _____, R.D. Chapman, W. W. Cochran, and U. S. Seal. 1984. Radio-triggered anesthetic dart collar for recapturing large mammals. *Wildlife Society Bulletin* 12:69-74.
- Mielke, P. W., Jr., and K. J. Berry. 1982. An extended class of permutation techniques for matched pairs. *Commun. Stat.* 11:1197-1207.
- Milbank, D. 1992. Academe gets lessons from big business. *Wall Street Journal* 15 Dec 92.

Mohr, C. O. 1947. Tables of equivalent populations of North American small mammals. *Am. Midl. Nat.* 37:223-249.

① * Moore, D. E. III, and R. Smith. 1991. The red wolf as a model for carnivore re-introductions. in J. H. W. Gipps, ed. *Beyond Captive Breeding. Symp. Zool. Soc. Lond.* 62:263-278

Nowak, R. M. 1979. North American Quaternary Canis. Museum of Natural History. University of Kansas Monograph 6.

O'Brien, S. J., and E. Mayr. 1991. Bureaucratic mischief: recognizing endangered species and subspecies. *Science* 251:1187-1188

Ott, L. 1988. An introduction to statistical methods and data analysis, 3rd ed. Boston: PWS-Kent Publ. Co.

Ounsted, M. L. 1991. Re-introducing birds: lessons to be learned for mammals. in J. H. W. Gipps, ed. *Beyond Captive Breeding. Symp. Zool. Soc. Lond.* 62:75-85.

* Paquet, P. C. 1991. Winter spatial relationships of wolves and coyotes in Riding Mountain National Park, Manitoba. *J. Mammal* 72:397-401.

* Parker, W. T. 1987. A plan for reestablishing the red wolf on Alligator River National Wildlife Refuge, North Carolina. Red Wolf Management Series: Technical Report No. 1. Atlanta, GA: U.S. Fish and Wildlife Service

 and M. K. Phillips. 1991. Application of the experimental population designation to recovery of red wolves. *Wildl. Soc. Bull.* 19:73-79.

- * Peek, J. M., L. D. Mech, D. E. Brown, J. H. Shaw, S. R. Kellert, and V. Van Ballenberghe. 1991. Restoration of wolves in North America.—Wildl. Soc. Tech. Rev. 91-1.
- * Phillips, M. K. 1987. Reestablishment of red wolves in the Alligator River National Wildlife Refuge, North Carolina: Progress Report 1. Atlanta, Georgia: U.S. Fish and Wildlife Service.
- Pianka, E. R. 1974. Niche overlap and diffuse competition. Proc. Nat. Acad. Sci. 71:2141-2145.
- Powell, R. A. 1987. Black bear home range overlap in North Carolina and the concept of home range applied to black bears. Int. Conf. Bear Res. and Manage. 7:235-242.
- * Riley, G. A., and R. T. McBride. 1972. A survey of the red wolf (*Canis rufus*). USDI Spec. Sci. Rept. Wildl. No. 162., Washington, D.C. Pp.1-15.
- Romesburg, H. C. 1981. Wildlife science: gaining reliable knowledge. J. Wildl. Manage. 45:293-313.
- Saltz, D., and P. U. Alkon. 1985. A simple computer-aided method for estimating radio-location error. J. Wildl. Manage. 49:664-668.
- Sargeant, A. B. 1982. A case history of a dynamic resource—the red fox. in G. C. Sanderson, ed., Midwest Furbearer Management. Proc. 1981 Symp., Midwest Fish Wildl. Conf., Wichita, Kansas.

- _____, and S. H. Allen. 1989. Observed interactions between coyotes and red foxes. *J. Mammal* 70:631-633.
- _____, S. H. Allen, and J. O. Hastings. 1987. Spatial relations between sympatric coyotes and red foxes in North Dakota. *J. Wildl. Manage.* 51:285-293.
- SAS Institute Inc. 1987. SAS Language Guide for Personal Computers, Version 6.04 Edition. Cary, N.C.: SAS Institute Inc.
- Schaffer, R. H. 1992. The quality quagmire. *CIO* 1 Nov 92, p.28-30.
- _____, and H. A. Thomson. 1992. Successful change programs begin with results. *Harv. Bus. Rev.* Jan-Feb. p. 80-89.
- Shanks, R. E. 1954. Reference list of native plants in the Great Smoky Mountains. unpubl. list, Botany Dept., University of Tennessee, Knoxville TN.
- * Shaw, J. H. 1975. Ecology, behavior, and systematics of the red wolf (*Canis rufus*). PhD Dissertation, Yale Univ.
- Slauson, W. L., B. S. Cade, and J. D. Richards. 1991. User manual for BLOSSOM statistical software. Nat. Ecol. Res. Center, U. S. Fish and Wildlife Service. Fort Collins, Colorado.
- Smith, G. J., J. R. Cary, and O. J. Rongstad. 1981. Sampling strategies for radio-tracking coyotes. *Wildl. Soc. Bull.* 9:88-93.
- Starling, G. 1988. Strategies for policy making. Dorsey Press: Chicago.

- Stokey, E., and R. Zeckhauser. 1978. A primer for policy analysis. New York: W.W. Norton and Co.
- Swed, F. S., and C. Eisenhart. 1943. Tables for testing randomness of grouping in a sequence of alternatives. *Annals of Math. Stat.* 14:66-87.
- Taguchi, G., and D. Clausing. 1990. Robust quality. *Harv. Bus. Rev.* Jan/Feb:65-75.
- Theberge, J. B., and C. H. R. Wedeles. 1989. Prey selection and habitat partitioning in sympatric coyote and red fox populations, southwest Yukon. *Can. J. Zool.* 67:1285-1290.
- * USFWS. 1990. A proposal to reintroduce the red wolf into Great Smoky Mountains National Park. Atlanta, GA: U.S. Fish and Wildl. Serv.
- U. T. 1992. Institutes for Productivity Through Quality. Knoxville, Tennessee: Management Development Center, University of Tennessee
- Walters, C. 1986. Adaptive management of renewable resources. MacMillan: New York.
- Waples, R. S. 1991. Definition of "species" under the Endangered Species Act: application to pacific salmon. NOAA Technical Memorandum NMFS F/NWC-194. Seattle, WA; U.S. Dept. Commerce National Oceanic Atmospheric Administration, National Marine Fisheries Service Northwest Fisheries Center.

- Wayne, R. K., and S. M. Jenks. 1991. Mitochondrial DNA analysis implying extensive hybridization of the endangered red wolf, Canis rufus. Nature 351:565-568.
- Weise, T. F., W. L. Robinson, R. A. Hook, and L. D. Mech. 1975. An experimental translocation of the eastern timber wolf. Audubon Conserv. Rept. No. 5
- White, G. C., and R. A. Garrott. 1990. Analysis of radio-tracking data. San Diego: Academic Press.

APPENDIX

SAS code for test of inter-animal distance

```

options ls=75 ps=54;
*****
***** DATA COMPARE and PROC SORT
*****   Receives data from \SA8COMP.DAT, converts date to
*****   a single value for 'minutes'.
*****   Sorts data chronologically by the value of 'minutes'
*****   and the value of 'ID'.
*****;
data compare;
infile '\utms\spatial\SA8comp.dat';
input northing easting year month day ID hour min;
ID1=ID;
if month=1 then prevmo=0;
if month=2 then prevmo=31;
if month=3 then prevmo=59;
if month=4 then prevmo=90;
if month=5 then prevmo=120;
if month=6 then prevmo=151;
if month=7 then prevmo=181;
if month=8 then prevmo=212;
if month=9 then prevmo=243;
if month=10 then prevmo=273;
if month=11 then prevmo=304;
if month=12 then prevmo=334;
if year=91 then yearmin=0;
if year=92 then yearmin=1;
if hour=. then hour=0;
minutes=(yearmin*525600)+((prevmo+day)*1440)+(hour*60)+min;
proc sort; by minutes ID;
*****
***** DATA PAIRED
*****   Uses the data from COMPARE to calculate distance between
*****   locations falling within the specified separation in
*****   'minutes'.
*****   Deletes observations falling outside separation in 'minutes'.
*****;
data paired; set compare;
if ID^=ID1 then ID2=ID;
z=lag(minutes);
dmin=dif(minutes);
IDdif=dif(ID);
nordif=dif(northing);
eastdif=dif(easting);

```



```

distance=sqrt((nordif**2)+(eastdif**2));
if dmin>1440 or IDdif=0 then delete;
if ID>0 then type='paired';
if dmin=. then delete;
*****
***** DATA TWO
***** Generates random numbers called 'number', adds them to the
***** data-set COMPARE, and sorts the data set by 'number' and 'id'.
*****
data two; set compare;
if year=89 then delete;
number=ranuni(1002);
proc sort; by number ID;
*****
***** DATA RANDOM
***** Calculates inter-animal distance for locations listed
***** by succession of random numbers in TWO.
*****
data random; set two;
z=lag(number);
IDdif=diff(ID);
nordif=diff(northing);
eastdif=diff(easting);
distance=sqrt((nordif**2)+(eastdif**2));
if ID>0 then type='random';
*****
***** DATA ALL
***** Merges data sets PAIRED and RANDOM
***** and calculates and adds log10 of distance
***** to the new dataset ALL
*****
data all; merge paired random; by type;
if distance=0 then
  ldist=.;
else
  ldist=log10(distance);
*****
***** PROCEDURES
***** Calculates and tests Wilcoxon rank scores between
***** inter-animal distances from PAIRED and RANDOM
*****
title1 'Simultaneous vs Random Distance Comparison';
***** any way to print ID1 and ID2 ?;
proc means mean max min std; var distance; by type;
proc npar1way wilcoxon; var distance; class type;
run;

```

VITA

Gregory Thomas Matthew Schildwachter was born in Bronxville, New York on 17 September 1964. He grew up in Oconee County, Georgia, and Westchester County, New York, where he attended high school at Byram Hills High, graduating in 1982. In 1989, he earned a Bachelor of Science in Forest Resources (concentration: fish and wildlife biology) from the School of Forest Resources at the University of Georgia.

After graduation from Georgia, he worked with the Southeastern Cooperative Wildlife Disease Study in Athens, Georgia, and the Feline Research Program of the Caesar Kleberg Wildlife Research Institute in Kingsville, Texas. He began work on a Master of Science in wildlife science at the University of Tennessee in 1991.

He now is developing a research project on the management of endangered species on private land, to be conducted as a dissertation project for the Doctor of Philosophy in Forestry at the University of Montana.