The Endangered Water Shrew

Project Report

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between

Arizona State University

and

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Heritage Fund Program

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TABLE OF CONTENTS

ABSTRACT

The Arizona water shrew, *Sorex palustris navigator*, exists as a single, isolated population in the White Mountains of eastern Arizona. Given recent and historical habitat alterations affecting riparian habitats within its general range, and the sparse distributional data on the species (only 11 trappings as of 1994), the current project sought:

1) to obtain data on the distribution of water shrews amongst the limited number of perennial, high elevation streams within the White Mountains region;

2) to determine the distribution and abundance of water shrews along the linear extent of those streams in which they do occur;

3) to establish further data on the riparian habitat characteristics which are important to the Arizona population; and (given sufficient trapping data)

4) to evaluate the stability of the Arizona population based upon its distribution, abundance and habitat relations.

Two seasons of intensive trapping on the Apache National Forest yielded only **two (2)** additional water shrews (one at Burro Creek and one above Phelps Cabin) and only one new local, the Burro Creek site (Objective 1). These sparse distributional data preclude both the estimation of the species' linear range upon occupied streams (which requires trappings from a minimum of two sites along a single stream) and estimation of local population densities (which requires at least two separate trappings at each of several sites). Therefore, neither linear range along streams (Objective 2) nor population stability (Objective 4) could be addressed. Logistic regression of habitat characteristics on the presence or absence of shrews (Objective 3) yielded only elevation as significant at $\alpha = 0.05$ ($p = 0.0043$). At $\alpha = 0.10$, bank slope angle was also significant under forward selection procedures, but was dropped from the regression model under stepwise selection procedures. Recommendations for prioritizing future trapping efforts are discussed.

INTRODUCTION AND OBJECTIVES

State and federal wildlife managers are charged with conserving natural species diversity on public lands. With this goal in mind the Arizona Game and Fish Department Heritage Fund program seeks to have the distribution and abundance of potentially rare and endangered species within the state inventoried. One such species is *Sorex palustris navigator* which exists widely throughout much of the mountainous western states, but as only a single, isolated population within the White Mountains of eastern Arizona.

Water shrews are inhabitants of cold, swift running, boreal streams that offer cover in the form of shrubs and forbs, exposed roots, logs, rocks and overhanging banks (Baker 1983, Banfield 1974, Conaway 1952). A study by Clark (1973) indicated that water shrews were most common in habitats of approximately seventy-five percent (75%) ground cover (Beneski and Stinson 1987, citing: Clark 1973). Beaver (*Castor canadensis*) activities also may facilitate water shrews through creation of appropriate local habitat (Wrigley et al. 1979). Water shrews have occasionally been trapped in slower moving streams and even in dry, ephemeral creek beds (Kinsella 1967). Their diet consists largely of small fish, insects and other invertebrates, some plant material and small mammals (Beneski and Stinson 1987). Densities of water shrews are believed to be low (home ranges of 0.2 to 0.3 ha.) compared to other shrews and many small mammals (Beneski and Stinson 1987, citing: Buckner and Ray 1968; Kirkland and Schmidt 1982; Nagorsen and Peterson 1981).

The Arizona population of *S. p. navigator* is of biological interest for a number of reasons. First, isolation from other conspecific populations allows for population differentiation through genetic drift and the development of novel genetic characteristics through mutation. Novel characteristics could be spread throughout the species upon renewed contact of populations and the recommencement of gene flow. Long lasting isolation can lead to the accumulation of enough genetic differences to create reproductive isolation between populations, thus forming new species (Mayr 1963). These processes are major evolutionary forces responsible for biodiversity per se. Second, sky islands such as Mount Graham and, in this case, Mount Baldy are of interest to extinction theorists (Brown 1971) and metapopulation theorists (e.g. Gilpin 1986, 1987) concerned with issues of conservation.

Specific management of this population may be necessary given both its limited known range and historical habitat alterations within that range. Two of the three historical trapping sites given by Hoffmeister (1986) have been drastically altered. Horseshoe Cienega on the White Mountain Apache Reservation has become Horseshoe Cienega Lake. KP Cienega (cited as Punta Prieta by Hoffmeister) has been dammed as a cattle tank and converted to a commercial campground. Although Sheep's Crossing (West Fork of the Little Colorado River) has been minimally altered, despite substantial efforts no water shrews have been trapped below the road and associated bridge that cross the river just below the Mount Baldy Wilderness Area.

If the main dispersal corridors for water shrews are the streams that they inhabit (a reasonably conservative assumption), habitat alteration above river forks could isolate multiple subpopulations, thereby cutting off dispersal corridors and drastically increasing the chances of extinction for this population as a whole. Given the potential deleterious effects of recent habitat alterations and the sparse data on the distribution and abundance of this species in the White Mountains of Arizona, this research sought additional distributional data, habitat correlates and an assessment of population stability. Specifically the current project sought:

1) to obtain data on the distribution of water shrews amongst the limited number of perennial, high elevation streams within the White Mountains region;

2) to determine the distribution and abundance of water shrews along the linear

extent of those streams in which they do occur;

3) to establish further data on the riparian habitat characteristics which are important to the Arizona population; and (given sufficient trapping data)

4) to evaluate the stability of the Arizona population based upon its distribution, abundance and habitat relations.

METHODS

Selection of trapping sites: Initially, potential trapping sites were identified objectively by marking all streams that appeared to be perennial for several miles above an elevation of 8000 feet using topological maps (7.5 minute series) of the Apache National Forest provided by Terry Myers of the Apache-Sitgreaves National Forest. A list of these streams was attached to the original proposal submitted to the Heritage Fund Program and is attached as Appendix A to this report. Thereafter, visual inspection of these streams revealed that many did not maintain sufficient flow to be considered perennial at or above 8000 feet. In addition, many streams showed substantial habitat alteration (damming and diversion). These streams were stricken from the potential list of trapping sites (see Table 1, below).

Once streams to be surveyed had been identified, trapping sites were located on each. Ideally, we sought to trap along the length of each stream at three different elevations (8000, 8500 and 9000 feet) so that a linear range for *S. p. navigator* along each drainage where it occurs could be estimated. The trapping methodologies used in this survey sought to trap these animals as effectively (often) as possible with a minimum of trap mortality. All traps were checked at least twice daily: as close to dawn and as close to dusk as possible. Overnight trap mortality was presumed to be most likely. Therefore, trapping sites were constrained by a need for quick and relatively convenient access to ensure that traps could be checked rapidly each morning to minimize trap deaths. This need affected our ability to trap at all of the ideal elevational targets. However, trapping was usually attempted at two to three different elevations along each stream that spanned above 9000 feet.

Trapping:

Pitfall traps. Shrew trapping was undertaken using several methodologies. First, pitfall traps (one gallon paint cans) were set at one hundred meter intervals immediately along stream edges. In his extensive trapping study, Conaway (1952) never took water shrews more than 7 inches (approximately 16cm) from the water line. During the 1995 trapping season, at least three (3) pitfalls were set at each site at 50 meter intervals. Visual inspection of a number of potential high elevation streams in the early summer of 1996 eliminated many potential trapping sites from the pool of streams to be trapped. Therefore, with fewer streams to be sampled, pitfalls were increased to six (6) per sampling area, again set at 100 meter intervals. By increasing the number of pitfalls set per sampling area, we hoped to increase the likelihood of overlapping one or more water shrew territories.

Table 1: List of streams stricken from the list of potential streams to be surveyed after visual inspection or for other reasons.

STREAM	TOWNSHIP/RANGE	FS DISTRICT
Riggs Creek	T7N, R29E	Alpine (Ap)
Benton Creek	T7N, R29E	Ap, Springerville (Sp)
Colter Creek	T7N-T6N, R29E	Ap
Coyote Creek	T7N, R31E	Ap
Maime Creek	T7N, R31E	Ap
Nutrioso Creek	T6N, R30E	Ap
Auger Creek	T6N, R30E	Ap
Boggy Creek	T5N, R27E	Sp, Ap
Centerfire Creek	T5N, R27E	Sp, Ap
Black River, W. Fork Tributary	T5N, R27E	Sp
Campbell Blue	T5N, R29E	Ap
Coyote Creek	T5N, R29E-R30E	Ap
Horton Creek	T4N, R28E	Ap
Willow Creek	T4N, R28E-R29E	Ap
Bear Creek	T4N-T3½N, R28E	Ap
Thomas Creek	T4N, R29E	Ap

Pitfalls were set so that the can opening was not more than one and one half inches higher than the existing water level and the trap was not more than four inches from the stream itself. A ramp of soil or gravel was fashioned around the lip of each pitfall to provide access to the trap opening. If possible, traps were set into the stream itself: that is, a soil and rock peninsula was constructed so that the pitfall was wholly contained within the preexisting stream and would intercept animals swimming along the preexisting stream edge. These methodologies proved effective during the Arizona Game and Fish Department survey of 1992 (Van Pelt personal communication). Where possible, all pitfalls were augmented with short metal runners from the outer bank edge of the trap extending six to eight inches into the bank from the trap. These short runners were deemed sufficient to channel water shrews wandering the banks into the trap itself. Pitfalls were often baited with small chunks of catfish, more to provide a means of survival for any trapped shrew than as an attractant to the animals. Because stream levels changed constantly, many pitfalls had to be reset on a daily basis due to a) flooding of the trap itself or b) a drop in the stream level which left the pitfall stranded high on the bank. Flooding was a major problem for pitfall trapping in areas around the Mount Baldy Wilderness Area.

Several other pitfall methods were attempted in an effort to increase the probability of trapping, which are mentioned here so that future trapping efforts may learn from our experience. First, floating pitfall traps were fashioned out of the same one gallon paint cans weighted with a small quantity of concrete in the bottom and surrounded with a wreath of vegetation to allow shrews that intercepted the cans in the water to climb onto the trap. These cans could be baited and attached to the stream bottom or edge with a line which allowed the trap to float in place and rise and fall with changing water levels. If the trap was to be set near the stream edge, the edge could be dug out under the trap to allow for it to fall with a drop in the stream level.

Second, we tried to set pitfalls at the stream edge as usual but to insert runners into the stream itself in the form of strong wire screening with a mesh sufficiently large to allow free flow of water through the runner but sufficiently small to force a passing water shrew to circumvent the barrier and drop into the pitfall at the stream edge.

Sherman Traps: Sherman traps were originally to be used only on streams where water shrews had previously been trapped in order to minimize trap mortality within the known range of the species. During the 1995 trapping season, Sherman traps were initially used along stream edges as an informal supplement to the shrew trapping effort and in order to allow more training of field assistants in the handling of small mammals of any kind. Towards the end of the 1995 season, both Sherman traps and pitfall traps were used in conjunction in order to increase the likelihood of trapping water shrews by any method. Pitfalls were included on historical trapping sites to validate the pitfall methodology also. Sherman traps were set on many of the streams in association with pitfalls during both trappings (see Appendix D). Each stream surveyed with Shermans was trapped for at least three (3) consecutive nights. During 1996, approximately 100 Sherman traps were set at five to seven meter intervals as close to the stream edge as possible and baited with oats to keep any rodents trapped alive. During the 1995 season, fifty (50) Sherman traps were used.

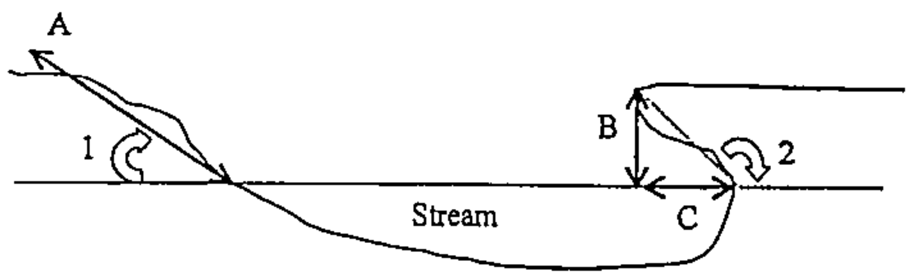
Riparian / Vegetative Sampling: Methods of riparian sampling were modified for the 1996 trapping season at which time fourteen (14) of the twenty-one (21) streams sampled in the previous season were resampled using the new methodology. Using these methods we sought to obtain an objective characterization of riparian and vegetative characteristics and cover along sites. Sampling was performed at six points at each site (i.e. if a single stream was trapped at three different elevations, each such site was sampled at six points for a total of 18 points along that stream). Sampling points were at 100 meter intervals and corresponded to pitfall trap sites for all streams trapped in the 1996 trapping season.

At the beginning of the project, characteristics of interest included stream characteristics (width, depth); bank characteristics (slope, overhang); herbaceous cover (percent cover or density, mean height); shrub cover (shrub density, percent cover); and other cover including rocks, roots and debris. During the sampling it became apparent that rocks provided no substantial cover in most areas and that debris was both changing and difficult to quantify objectively. Therefore, these potential measures were dropped from the sampling design. Root cover is also difficult to quantify objectively, therefore, we presumed that the amount of root cover on a stream would be a function of the number (density) and age (basal area) of trees around the stream. The revised sampling scheme obtained the following measures at each sampling point:

<u>Stream:</u> Stream depth was measured using a folding ruler at each bank and at stream center. Stream width was measured using a range finder or a simple tape measure on smaller streams. From these data, a rough estimate of stream cross-sectional area could be obtained.

<u>Bank:</u> Bank slope was assessed on each side of the stream at each sampling point (for a total of 12 measurements per site) using two methods. First, for non-overhanging banks, slope was obtained by direct measurement using a straight-edge and a clinometer. Second, two measures were taken at overhanging banks: the distance from the bank edge at the top of the overhang to the water surface, and the horizontal distance along the water surface from the top bank edge to the edge of the stream (Figure 1). From the second measurements, the tangent of the complementary bank slope angle could be calculated thus allowing total slope angle to be obtained for overhanging banks. Angles greater than 90° constitute overhanging banks.

Figure 1: Bank slope measurements taken in riparian / vegetative sampling (A - line of slope-angle 1, obtained with clinometer; B and C - measurements used to obtain angle 2).



Herbaceous Cover: Herbaceous cover was assessed on each side of the stream at each sampling point (for a total of 12 measures per sampling area). First, the presence or absence of herbaceous cover was noted. Second, a fixed open square (approximately 35cm X 35cm) was set at stream edge on the bank at each point and the percentage of the enclosed area covered by herbaceous plants was estimated. Second, the plant closest in proximity to each interior corner of the square was taken and measured for length to obtain an estimate of average herbaceous height at each such point.

Shrub Cover: Using a range finder (or tape measure where appropriate) shrub density was estimated by measuring the distance along the stream edge to the nearest shrub that provided cover to the stream itself. All such measurements were taken both upstream and downstream of each sampling point on both sides of the stream providing four measurements at each point and twenty-four per sampled stream site. These distances may then be used to estimate linear density of shrub cover along each stream (modified from Cox 1980). Using a tape measure, the radius of these same shrubs was also measured to obtain an estimate of the total area covered by these shrubs along the edges of each stream.

Tree Data: The density of trees and basal area were estimated using a standard point-centered quarter sampling method (Cox 1980). Essentially, distances to the nearest tree in each quarter are taken as in measurement of shrub density. However, we did not constrain ourselves to the stream edge because tree density in the area generally is expected to correlate with the amount of tree and root cover which may be provided to the stream. In addition, basal area may correlate with the amount of woody debris available to drop or wash into the stream to provide debris cover. Facing downstream, the four quarters measured at each sampling point were: right (side) upstream, left upstream, right downstream, and left downstream. Distance to the nearest tree in each quarter was measured with a range finder or tape measure as appropriate. The circumference at breast height of each such tree was also recorded to obtain estimates of basal area along the riparian zone.

Statistical Analysis:

Using these data and topological maps, the following stream characteristics were estimated or measured for analysis: elevation, stream width, stream cross-sectional area, bank slope, percent herbaceous cover, mean herbaceous height, shrub density, shrub area, tree density, and tree basal area. These characteristics were modeled as independent variables against binary data (shrew presence or absence) on each stream site in a logistic regression analysis using SAS PROC LOGISTIC. Because only two (2) water shrews were trapped during the course of this project, all historical trapping locations (Hoffmeister 1986, Hanna 1992, Smith 1993) included in the riparian / vegetative sampling were included in the statistical analysis as sites where water shrews had been trapped. Thus, six (6) trapping sites were deemed positive for the presence of water shrews and nineteen (19) were deemed negative.[1] A list of stream sites trapped and those included in the riparian / vegetative analysis is attached as Appendix B. Appendix B also includes photocopies of the topographical maps corresponding to sites trapped.

RESULTS AND DISCUSSION

Trapping: Trapping efforts yielded two (2) water shrews. Relevant trapping data are summarized below in Table 2.

Table 2: Summary of water shrew trapping data.

Number of Water Shrews	Date Trapped	Stream	Township / Range	Forest Service District
1	8/24-30/95	Burro Creek	T6N, R27E	Springerville
1	9/4/96	E. Fork Little Colorado	T6N, R27E	Springerville

[1] A validating assumption of this regression analysis, then, is that riparian characteristics of historical trapping sites have not changed too substantially since the time of trapping. For very recent trapping data (1992 to present), this assumption is largely valid. In addition, Smith (personal communication) states that the characteristics of Fish Creek (Springerville District off of State Highway 260) have not visibly changed since his trappings there in 1985 and 1987. Regarding the earlier historical trappings cited in Hoffmeister (1986), closer scrutiny of this assumption is warranted.

The Sheep Crossing area on the West Fork of the Little Colorado within and below the Mount Baldy Wilderness Area has probably not changed too drastically since the turn of century. The wilderness area and immediate surroundings are, and have been, subjected to minimal management disturbance other than low density cattle grazing and the building of State Route 273 near and across the stream. Therefore, we might expect Sheep Crossing to have retained many, if not most, of its historical riparian characteristics. (However, recall that no water shrews have been trapped below the SR273 bridge near Sheep Crossing). KP Cienega Creek is another story. The creek itself has been blocked and converted to a cattle tank. Just above the tank, a campground has been constructed. We would not expect the stream to have retained its original riparian characteristics in the immediate area of these alterations and for some distance below them. On the other hand, the stream above these alterations appears less disturbed. Therefore, the riparian sampling was conducted above the campground.

Both water shrews were taken in pitfall traps set at the stream edge. Floating pitfalls were unsuccessful at taking water shrews. However, only five (5) floating pitfalls were constructed late in the second (and last) trapping season. The hypothesized advantages of these traps included consistency of operation, due to lack of flooding, and specificity, as the only small mammal likely to be able to access these traps would be water shrews. We hoped that mammalian predators would not be able to pluck the bait (or any trapped shrews) out of these traps. Unfortunately, these types of traps could not be tested sufficiently given the short duration of their usage and the apparent rarity of water shrews in the area. Perhaps such traps could be tested in a more northern location where water shrews are more naturally abundant.

Pitfalls set in conjunction with screen mesh runners that penetrated the stream itself were also unsuccessful at taking water shrews. Although there may be some promise in this method, the mesh was not sufficiently large to prevent build-up of enough stream debris and snails to make the barriers complete. Once complete, these barriers diverted water over their tops and filled the associated pitfalls.

Despite 3600 Sherman trap nights, no water shrews were taken in Sherman traps. Oftentimes, the availability of Sherman traps for trapping shrews was diminished by up to one third as dozens of traps quickly filled with *Peromyscus* species.

Statistical Analysis

Initially, PROC LOGISTIC was run using both forward and stepwise procedures at an $\alpha = 0.05$ threshold for inclusion into the logistic regression model. Of all the independent variables modeled, only elevation was significant ($p = 0.0043$). In an effort to determine whether any of the other variables might help explain the presence or absence of water shrews, the α level was increased to 0.10 and the analyses repeated. Bank slope angle was found significant ($p = 0.0854$) under forward selection procedure, but dropped from the model under stepwise selection procedure per the Wald statistic criterion. Because the model included only one significant variable, no testing of the model was appropriate.

Given the association of water shrews with high elevation streams, the fact that elevation was significant in explaining the presence of water shrews comes as no surprise. In fact, we might be surprised if it had not been significant. However, a good number of high elevation streams were surveyed that failed to yield water shrews, including stretches of streams where water shrews had been trapped just above (e.g. Colter Reservoir below Phelps Cabin and West Fork of the Little Colorado below the Winn campground).

The marginal significance of bank slope angle in forward analysis may indicate that the age of each stream, in riparian terms, helps predict the occurrence of water shrews. Water shrews may be more likely to occur on streams where time has allowed erosion to undercut well-developed vegetational communities on the banks. Overhanging banks have been associated with the presence of water shrews in prior studies (Baker 1983, Banfield 1974, Conaway 1952). However, this variable was significant only at $\alpha = 0.10$ and, even at this inflated significance level, removed from the regression model under stepwise procedures.

Obviously, any species would require some habitat characteristics in order to survive. The fact that none of the numerous vegetative characteristics were found significant may be more indicative of the importance of metapopulation dynamics in determining current distributions than of a lack of importance of riparian and vegetational characteristics to the survival of this population. An underlying assumption of this type of study is that the species of interest could reach and populate all suitable habitats. In other words, habitat largely determines species presence and absence. Where all suitable habitats are within the range of dispersers, this assumption should hold much of the time. Where dispersers are isolated from other suitable habitats, however, chance extinctions become more significant in determining species ranges.

Therefore, we might expect both elevation and additional habitat characteristics to be significant in our statistical analysis, *if* all suitable riparian habitats were accessible to dispersing water shrews. The fact that none of the many additional habitat variables are significant leads us to seek other explanations. If dispersal corridors have been cut off due to recent desiccation of the southwest, chance extinctions could leave many suitable (and previously occupied) habitats uninhabited. Thus, elevation may still be significant in our analysis due to its general correlation with certain habitat types, whereas important specific and finer scale vegetative characteristics may go undetected due to the occurrence of many suitable, yet unoccupied streams in the analysis. For instance, it is certainly reasonable to assume that the species occurred on the East Fork of the Black River shortly before the climate warmed enough to isolate the confluence of the east and west forks below the preferred boreal habitat of the water shrew. The current lack of success in trapping on the East Fork could reflect either the difficulty of trapping water shrews (i.e. they occur there but have not yet been trapped), or extinction of the local population after the dispersal corridor was isolated. The available habitat within the East Fork above 8000 feet appears to be as suitable for the species as that of the West Fork just a few miles away.

CONCLUSIONS

It is difficult to draw conclusions regarding the vegetational and other habitat requirements of *S. p. navigator* in Arizona based upon such disparate trapping data. We do know that the occurrence of *S. p. navigator* in the White Mountains correlates with high elevation perennial streams. We reiterate that the occurrence of *S. p. navigator* in Arizona may reflect biogeographical artifacts more than species ecological correlates. In other words, although there appears to be much high elevation, perennial stream habitat available to the species in the White Mountains (and some other areas of Arizona), current distributions may result more from the recent desiccation of the southwest since the Pleistocene, and past (and unnoticed) extinction events in high elevation streams which currently appear suitable for this species.

The probability of long term persistence of the White Mountains population of water shrew can not be adequately addressed given available data. A reasonable analysis of population viability would require reasonable estimates of spatial distributions, including *both* species range *and* local population densities. Single individuals trapped once at single locations per stream afford insufficient data to estimate either local population density (minimum of two points per location required) or of species range (minimum of two points along each stream required) (DeBlase and Martin 1974, 1981). Estimating population size along any one stream would require, at a minimum, three trappings across two trapping locations. Insufficient data exist to make any reasonable assessment of population stability at this time. We discuss recommendations for obtaining sufficient data for such an analysis below. The lack of sufficient data undoubtedly reflects the difficulty of trapping water shrews where they do occur. The data may also indicate that the species has an extremely limited range. Until more data are available, conservative, low impact management of the Mount Baldy Wilderness and surrounding area is urged.

RECOMMENDATIONS

Clearly, additional data on the occurrence of *S. p. navigator* in the White Mountains are needed. The current data cluster around the Mount Baldy Wilderness Area above State Route 273. Historical data indicate that the shrew occurred at KP Cienega at the turn of the century. Before any informed assessment of population stability can be made, more data on the current distribution of the species must be obtained. Regarding those streams that the water shrew is known to occupy, these should be intensively sampled just below where animals have been trapped until additional trappings are made or until there is reasonable assurance that the linear limits of the distribution along each drainage have been reached. Assuming additional trapping efforts are successful, traps should be walked downstream until the linear distribution limits have been reached. Of course, care must be taken during this process to ensure that the species population on each drainage is not being systematically eliminated below the initial trapping location. In addition, some trapping efforts should be undertaken during early spring and late autumn in case the cooler temperatures during these seasons may be facilitating dispersal downstream that might be undetected during the normal summer and early autumn trapping period. Thereafter, other high elevation, perennial streams where the species has not yet been found should be sampled in an effort to identify all, as yet unknown, additional subpopulations in the White Mountains region. Based upon this information, below we list future trapping recommendations in order of our perceived priority.

I. White Mountain Apache Reservation

The water shrew occurred on the White River drainage at Horseshoe Cienega at the beginning of the century (Hoffmeister 1986). Horseshoe Cienega has since been altered and become Horseshoe Cienega Lake which may have been detrimental to dispersal of *S. p. navigator* through the presumed corridor of the confluence below the lake. If dispersal can be accomplished over land, then it would be presumed to be most effective where streams are at the shortest overland linear distance from each other. Dispersal may then be possible between many of the creeks of the West Fork of the Black River drainage. All perennial streams above 8000 feet in elevation from the White and Black river systems should be surveyed on the reservation. These streams, along with the Little Colorado streams, may constitute the last functional metapopulation system of *S. p. navigator* in Arizona. Needless to say, cooperation of the relevant managerial stewards of these streams may be critical to the long term persistence of this population. Specifically, the following streams should be surveyed:

White River Drainage:

The North Fork of the White River, both above and below Horseshoe Cienega Lake should be surveyed, including tributary creeks Paradise Creek, Ord Creek, Bear Cienega Creek, Horseshoe Creek, Snake Creek, Bog Creek and Smith Creek.

The East Fork of the White River and Deep Creek should be surveyed.

Black River Drainage:

All high elevation, perennial streams flowing into the Black River should be surveyed. These include: Big Bonito Creek, Little Bonito Creek, Lofer Cienega Creek, Boggy Creek, Flash Creek, Squaw Creek, Hurricane Creek, Pacheta Creek, Thompson Creek and Reservation Creek. Reservation Lake may also be surveyed to determine its potential effects on shrew distribution above and below it.

Little Colorado River Drainage:

Given recent trappings at Fish Creek by Smith, the White Mountain Reservoir should also be surveyed as the potential immediate dispersal bridge between Fish and Hall Creeks and, more indirectly, between these drainages and the East and West Forks of the Little Colorado River.

II. Mount Baldy Wilderness Area
Apache-Sitgreaves National Forests

On first inspection, we might believe that the Mount Baldy population is relatively healthy. However, this may be because it appears to be the only population. On closer inspection, we see that only one of the recent successful trap sites was below the actual confines of the wilderness area itself. This local (Fish Creek at State Highway 260) has been intensively surveyed on three separate occasions since the last trapping in 1987 with no success. In addition, this local has been sampled once every other year since 1987 by Andrew Smith for his Mammalogy course, also without success. The local population on Fish Creek may, in fact, be gone. Although this project surveyed the East and West Forks of the Little Colorado just below the wilderness area, no shrews were trapped there. No water shrews were found around the confluence of these forks in the Greer area. If dispersal is largely restricted to actual stream corridors, the populations on the East and West Forks may in fact be isolated from each other, diminishing their chances for long term persistence.

Little Colorado River Drainage:

The East and West Forks should be sampled from below State Route 273 through the Greer area. Specifically, the West Fork should be sampled at a minimum of three locations: below the Winn campground, just above Greer, and within the confluence of the two forks. The East Fork should be sampled just above and just below both SR273 and Colter Reservoir to determine what effect each of these alterations may have had on water shrew populations below the Phelps cabin area. In addition, the drainages into the Lee Valley Reservoir and the East Fork below the Reservoir should be sampled to determine the effects of the Reservoir itself on water shrew distribution. Of-course, the river should be sampled just above the Montlure Church Camp and within the confluence of the two forks.

Once the above areas have been surveyed, additional drainages such as Benny Creek, Hall Creek and Fish Creek should be more extensively searched. Survey of these latter drainages should be concurrent with surveys of the White Mountain Reservoir.

West Fork of the Black River:

The West Fork of the Black River should be more extensively surveyed below Forest Service Road 116 which is below the alteration caused by the road itself and below all recent trappings in the area (Thompson Ranch, Burro Creek). Once it has been determined that *S. p. navigator* occurs below the Thompson Ranch area, the river and its tributaries below the ranch should be surveyed towards its confluence with the East Fork of the Black River to determine the linear range of *S. p. navigator* along the drainage. In addition, surveys could be undertaken on Thompson Creek and the Black River above the Thompson Ranch area, although these reaches are of lower priority.

III. Other Forest Service Lands

Blue River Drainage:

Tributaries of the Blue River that extend perennially above 8000 feet should be surveyed as well as the Blue River itself above perhaps 7500 feet. It is reasonable to expect this species to occur somewhat below 8000 feet in elevation, although 8000 feet is a reasonable cut off for its preferred boreal habitat. Historically, one water shrew was trapped at Horseshoe Cienega at approximately 7800 feet. Specifically, KP Cienega Creek should be surveyed above the existing cattle tank near KP Cienega campground and below the tank wherever perennial flow recommences at this time.

These areas will not be convenient to reach and trapping, in all likelihood, will require long term efforts.

It may be most practical to undertake long term trapping efforts involving floating pitfall traps checked at longer durations (i.e. one or two weeks). In order to balance the benefits of obtaining data on these streams with the obvious cost of near certain trap deaths, traps could be set at high density within several areas likely to span approximately two, but no more, water shrew territories, on reaches that would be assumed to support many such territories. Hopefully, floating pitfalls would 1) allow more species specific trapping, 2) be less likely to flood, and 3) be less accessible to potential scavengers. Pitfalls set at high density in limited areas may be most likely to take any water shrews that do occur there without substantial effect on the local populations as a whole.

East Fork of the Black River:

The East Fork of the Black River should be surveyed on a long term basis at several points above 8000 feet. The streams in this system appear to be ideal for water shrews, yet recent trapping efforts by Hanna (1992) and in the current survey have failed to yield any specimens. Long term trapping efforts such as those suggested for the Blue River Drainage above may be necessary along these streams.

Escudilla Mountain Wilderness Area:

There are few streams that are perennial above 8000 feet running off of Escudilla Mountain. Therefore, this potential water shrew habitat is of lower priority in our opinion than all of the potential and actual habitats listed above. However, the perennial streams coming out of the wilderness area are of generally good quality (e.g. Maime and Coyote Creeks). If water shrews are found along any of these drainages, it may be indicative of the species potential dispersal ability or tenacity at holding on in limited territories. Failure to obtain water shrews after long term trapping efforts would support a hypothesis of local extinction due to natural reduction of habitat.

New Mexico:

Finally, the high elevation streams on Forest Service lands across the state border in New Mexico should be surveyed if we are to obtain a complete picture of the potential metapopulation dynamics of the Arizona water shrew.

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