Scaling up of small mammal research in Denali National Park and Preserve:
Extending the Denali Long-Term Ecological Monitoring program.

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1. Introduction

The first seven years of Denali LTEM has seen almost exclusive attention paid to the Rock Creek watershed in the eastern frontcountry of Denali National Park and Preserve. The choice of Rock Creek has provided advantages for working out monitoring protocols for several LTEM components during this initial phase of the program, the most notable of which is its accessibility. However, efforts need to be made to extend the preliminary work performed at Rock Creek to the rest of the park. This report presents options for scaling up the small mammal component, as well as some issues that will need to be decided for Denali LTEM as a whole.

Decisions that have been made during the first seven years in Rock Creek may or may not be the best decisions for an extended monitoring program beyond this watershed. We submit that all aspects of a monitoring protocol should be revisited, from what measurements are appropriate to where and when they should be taken. If funding and access to the park were unlimited then this would be unnecessary; we could simply replicate what we are doing in Rock Creek to several randomly selected sites throughout the park. Instead, we must confront reality and recognize that we will need to make tradeoffs as we extend monitoring to the rest of the park.

1.1 Population assessment methods

Several alternative methods exist for assessing animal populations, each with advantages and disadvantages. Which method is appropriate depends on several factors such as the species of interest and the objectives of the study. Figure 1 illustrates the relationships between some of the major population assessment techniques available. We will first consider these alternative methods in light of the small mammal research project of Denali LTEM.

1.1.1 Indices versus parameter estimation

The first option concerns the type of measures that will be taken: index-based or process-based parameter estimation (Lancia *et al*, 1994; Thompson *et al*, 1998). An index is a relatively easy measure to make, however, at its best it can only measure relative abundance (Lancia *et al*, 1994). A single measurement tells us nothing of the population. Some index methods that could be used with small mammals include fecal pellet counts, artifact counts, and trapping (Krebs, 1994). Pellet counts have been used as an index of abundance for several mammal species, including field mice. However, species identification based on fecal pellets may be impossible, resulting in the loss of monitoring information on individual species. Artifact counts are similar to pellet counts. Small mammals in Denali burrow beneath the snow during winter, leaving trails in the vegetation after snowmelt. Throughout the summer, they continue to make trails through the vegetation. These trails could be counted along a transect for a relative index of abundance. As with pellet counts, species-level distinctions would not be possible. Another index can be obtained by opening traps for a period of time and calculating the average number of animals caught per trap per day. No marking of animals would be done and no opportunity for recapture exists. Therefore, the result is an index for abundance, not an estimate of abundance.

For indices to be useful, we must be able to make comparisons across time and/or space. These are not absolute comparisons (site A has twice as many animals as site B), but are only comparisons of relative abundance (site A has more animals than site B). Even so, there are necessary assumptions in making these comparisons that might not be met. Regardless of what is being counted to generate the index, a valid comparison requires the same probability of observation for both sites and/or times being compared (Krebs 1994). When trapping, the probability of capture must be the same, which we know from seven years of data from Denali LTEM is not the case. The probability of capture varies with both space and time, making all direct comparisons suspect. The assumption of equal probability of observation may be more reasonable when counting pellets or trails, but even here there may be differences between sites and/or times that impact observation. Different vegetation types and climate (e.g., rainfall and temperature) may affect the detection of both pellets and trails through processes such as pellet decomposition and obliterating trails.

Alternatively, estimates of population parameters such as abundance, recruitment, and survival are more difficult to obtain than indices, but they allow for a statistically sound measure of the current status of the population as well as an indication of where it is going (Thompson *et al*, 1998). For example, if a population is on the verge of collapse because survival has suddenly decreased, a monitoring effort would be well served by detecting the problem before it occurs rather than after the population has crashed. An indication of the cause of the crash would be invaluable when determining possible management action that can be taken to either prevent or compensate for the problem. Given the limited usefulness of indices and the benefit of obtaining true parameter estimates, we make the decision to invest our efforts into the second course of action, estimating relevant population parameters.

1.1.2 Census and subplot counts

The next branch on our decision tree considers whether every individual can be observed (Lancia *et al*, 1994). If so, then a complete census is in order, which would lead to determining the true abundance. It seems ludicrous to even consider identifying every small mammal within DNPP. Even at the level of a watershed, a census would be unworkable. An alternative is to select subplots of a manageable size where we could do complete counts for a smaller sample of the park or watershed. However, given the terrain and vegetation encountered throughout DNPP, the size of the species we are dealing with, and the swings in abundance we have seen in the past, the effort expended to accurately count individuals makes this an impractical option. Enclosures would most likely be needed to contain the animals while a count is in progress and the number of samples required would likely be high. We submit that any kind of census or count method for small mammals in DNPP cannot be considered a viable option.

1.1.3 Capture-recapture versus removal methods

We are now to the final branch on our decision tree, recognizing that some form of capture method will be the best population assessment tool for small mammals in DNPP. Capture methods are generally most appropriate when individuals are difficult to observe or count, but there is a good chance that some can be captured (Lancia *et al*, 1994), and this would seem to be the case here. The question now becomes one of which capture method to use.

Animals can either be killed and removed permanently from the site or they can be marked and released to be potentially captured again, either of which requires the added cost and time of handling individual animals.

Removal methods are commonly used in hunting situations where the researcher is separate from those who handle the animals (Lancia *et al*, 1994). This is certainly not the situation here as the National Park Service will undoubtedly never sanction a hunting season on voles within the park. The approach with small mammals within DNPP would be to have sampling events where new captures are removed from the population, resulting in a savings of time and equipment with no marking required and the certainty that any animal captured is a new capture. There are some drawbacks to removal methods (White *et al*, 1982). Removal trapping could greatly alter the system we are trying to monitor, especially in areas with potentially low population levels as has been observed in DNPP. Most capture analyses assume population closure (no births, deaths, immigration, or emigration) during the course of sampling. Removing individuals can change the population enough to violate these assumptions. For example, the removal of several individuals can create opportunities for others to move into the area, adding individuals to the population that would not have been there otherwise. Additionally, this may result in the failure to obtain estimates because the method requires a measurable depletion in the population due to the removals. When estimates are obtained, their associated variances tend to be larger than for capture-recapture analyses. Lastly, removal methods assume a constant probability of capture over the course of the trapping, an assumption that cannot be tested and may not hold.

The question of how removal methods might alter the population being studied warrants further discussion. Voles in DNPP are capable of producing two new generations in a single summer; a newborn at the start of summer may have its own offspring by summer's end. Each female individual removed in the early summer will not only reduce the population by herself, but potentially by seven or more by the end of summer. For example, if five females were removed during the first trapping session, there could be 35 to 50 fewer individuals in the population at the end of the season. This could lead to a downward trend within and between years that is itself a result of the monitoring. Another possibility arises when considering that there could be a genetic-based proclivity to being trapped. If trapped animals are removed from the population and not allowed to reproduce, then artificial selection can occur, resulting in a population that is less likely to be trapped. This could appear as a downward trend, when in fact the population size is actually stable, but fewer animals in the area are prone to being captured. In the first case we find a trend that is the direct result of the monitoring. In the second we detect a trend that does not exist. The possibility of either of these scenarios is unacceptable in a monitoring program.

Capture-recapture methods allow for much more variability in their analysis (White *et al*, 1982). Specifically, the assumption of equal capture probabilities can be relaxed until a model is found that works (Otis *et al*, 1978, Thompson *et al*, 1998). If this assumption does hold, then the null model, M_0, can be used which estimates the number of individuals in the population (N), and a single probability of capture (p). If the probability of capture tends to change after an individual has been caught once, then model M_b can be used which allows for a probability of first capture (p_1) that differs from the probability of subsequent captures (p_2). If the capture probability varies with time, then model M_t is used which allows for a different capture probability for every capture occasion. Model M_h is available when every individual has a unique capture probability. These last three models can also be used together, resulting in four additional models: M_{tb}, M_{th}, M_{bh}, and M_{tbh}. Capture-recapture methods gives you the opportunity to match your data to one of eight possible models, resulting in better estimates with smaller variances.

We therefore establish as a basis for the remainder of this report that small mammal research in Denali will continue to use capture-recapture methods to estimate process-based population parameters. Despite being a more costly choice requiring the marking of individuals and more frequent trap checks, our efforts will provide information more useful and better suited to a monitoring effort.

1.2 Intensive and extensive monitoring

With the type of measure determined, the design consideration then turns to where and when the measurements should be made. In other words, what is the appropriate spatial and temporal intensity? This is the over-arching question that applies to every project involved in Denali LTEM and, at least to some extent, needs to be resolved for the program as a whole. Are we going to have an extensive monitoring program with many monitoring locations throughout the park, or are we going to have an intensive monitoring program with fewer locations monitored more closely? Can we have both? If not, what is an acceptable compromise that leaves us with meaningful information for a sufficient portion of the park? The remainder of this report explores the question of appropriate temporal and spatial intensities for Denali LTEM, particularly as it applies to the small mammal component.

2. Temporal Intensity

The temporal intensity of a sampling design concerns the interplay of many factors. The foremost consideration is the life history of the species being studied. We must choose temporal frames that are relevant to what we are trying to monitor.

2.1 Definition of sampling events

In addressing temporal intensity options for small mammal monitoring, it is helpful to review aspects of mark-recapture methods. At a given sampling location, a network of traps are left open for a period of time. The traps are then checked, new animals are marked, and the traps are reset. After another period of time the traps are checked again. This continues until the final trap check is complete and the traps are collected. This entire scenario defines a single **primary sampling event**, while each trap-check occasion is called a **secondary sampling event**. One primary sampling event consists of one or more secondary sampling events. When addressing temporal issues with small mammal monitoring, it is clear we have two different time scales to consider, one concerning the primary sampling events and the other concerning the secondary sampling events. As depicted in the timeline in Figure 2, these two time scales result in four critical elements to be considered in the design of a capture-recapture study: (1) the total number of primary sampling events, (2) the time interval between primary sampling events, (3) the total number of secondary sampling events within each primary event, and (4) the time interval between secondary sampling events within each primary event.

2.2 Requirements for population parameter estimation

Having established that we are interested in estimating survival and recruitment along with abundance, we must understand what is minimally required in order to obtain these estimates. A primary sampling event with a single secondary sampling event would only provide an index of abundance, i.e., the number of individuals captured (Thompson *et al*, 1998). At a minimum, we will need two secondary sampling events within each primary event to get an estimate of abundance. Similarly, a single primary event does not allow us to estimate survival or recruitment. To do so, we need a minimum of two primary sampling events (Pollock *et al*, 1990).

2.3 Minimum sampling scenario

Based on the previous paragraph, we can state that our minimum temporal sampling effort for a single location is two primary sampling events, each comprised of two secondary sampling events. With this sampling design, we can estimate abundance, recruitment, and survival. However, it must be noted that this design does not guarantee that recruitment and survival can be estimated. There remains the possibility that, given inadequate captures and recaptures in either primary sampling event, these attributes cannot be estimated (Thompson *et al*, 1998). It is also important to recognize that this sampling design greatly limits the analysis that can be performed by requiring that model M_0 be used (Otis *et al*, 1978). As described in section 1.1.3, this is the simplest model and assumes that capture probabilities are the same for all individuals and all secondary sampling events. Is this a realistic limitation to make? In 1998, there were 39 primary sampling events and estimates made for two different species. Of the resulting 78 population models run, only 27 (approximately one-third) used model M_0, corresponding to occasions when few animals were caught. It appears that this minimum sampling scenario would often result in an inappropriate analysis, but it nonetheless defines one end of the spectrum to be considered.

2.4 Maximum sampling scenario

On the opposite end of the spectrum, we can characterize our Rock Creek efforts as the maximum temporal sampling design for a single location. Most recently, we had five primary sampling occasions throughout the field season, each with 12 secondary sampling events (Rexstad, 1996). The secondary sampling events were conducted three times per day to minimize trap mortalities, which translates to a primary sampling event duration of four days. The entire field season is approximately 10 to 12 weeks in length, allowing for two weeks between primary sampling events. This intensive sampling design has been optimized over the past seven seasons. Adding more secondary events provides little improvement in estimates and potentially could lead to the violation of closure assumptions. With primary sampling events two weeks apart, there are sufficient numbers of individuals being caught in successive primary events for reliable estimation of survival and recruitment. Increasing the number of primary sampling events beyond five appears to be unnecessary.

2.5 Intermediate sampling scenarios

Between these two extremes in temporal intensity lie intermediate sampling scenarios of varying numbers of primary and secondary sampling events. To successfully estimate survival and recruitment with the minimum sampling scenario, there must be a sufficient number of individuals caught in both primary sampling events. Because of the short life span of these animals, the primary events need to be no more than two to three weeks apart. With only two primary sampling events, a large portion of the field season would be left unsampled, resulting in an incomplete picture of population dynamics.

Increasing the number of secondary sampling events beyond two seems to be important. Tests were run in the early years of the Rock Creek studies that suggested four days provided precise estimates with little benefit from increasing to five or more days. As mentioned earlier, abundance estimates are calculated with the assumption of population closure (no births, deaths, immigration, or emigration). If there are too many secondary sampling events or they are spaced too far apart, this assumption can be violated, resulting in imprecise estimates. The secondary events should be spaced so that there is little or no trap mortality caused by long stays in the traps. Ideally, secondary events should be within 12 hours of each other (Rexstad, 1996).

3. Spatial Intensity

The spatial intensity of a sampling design can be affected at three different levels: (1) the size of a trapping grid, (2) the number of grids at a sampling location, and (3) the number of sampling locations to be monitored. As with temporal issues, the optimal spatial extent to sample must be relevant to the life history of the species being studied.

3.1 Trapping grids

At the smallest spatial scale, we can change the number of traps that comprise a single trapping grid. As determined from population densities and home range size, the optimal plot size at Rock Creek was a grid of 10 by 10 (100 traps) spaced 10 m apart (Rexstad, 1996). We presume that this grid size will continue to be optimal, however we can reexamine this question now that we have seven years worth of capture data. We can also change the spatial intensity by varying the number of trapping grids used at a location. Rock Creek currently has four grids established. A great deal of time would go wasted if a field crew was to sample a location for four days and only use one grid. On the other hand, there is a limit to how much gear and supplies can be carried into areas with difficult access. Typically, three people can carry enough equipment for three grids and a base camp, suggesting a reasonable number of grids that is large enough to account for within-location heterogeneity and small enough to be manageable by a field crew. So if we say each location is to be sampled with three 100-trap grids, the question remains, how many locations do we need? Before a number can be determined, there are other issues that need to be addressed first, some theoretical and some practical.

3.2 Accessibility issues

From a practical standpoint, most of the park has difficult if not impossible access. To set up sampling locations more than even a few kilometers from the park road is unworkable without some sort of air support. Assuming we will need to carry gear and supplies to remote sites forces us to limit potential sampling locations to those areas accessible from the park road, say, within 10 km. This raises another point that may prove difficult with the Park Service. It is park policy that backcountry users cannot establish camps within sight of the park road. Much if not most of the area within 10 km of the park road is also within sight of the park road, the most notable exception being the forested areas along the first 12 miles of the road. If the visibility policy is to also pertain to research camps, then that will greatly reduce the potential sample locations even further. We have gone from a park-wide monitoring program to one with a very narrow scope. Some of the ramifications of this are explored below. We are monitoring the park because we care about it. It makes no sense to exclude the parts we care most about from that monitoring.

3.3 Scope of inference

Regardless of the required number of sampling locations, we must also be concerned with how those locations will be selected. Rock Creek was chosen almost by default. Of paramount importance is the need for some statement of what this monitoring program is monitoring. If it is the entire park, then the sampling locations chosen must be representative of the entire park. This means that we cannot limit potential sampling locations to the park road and then pretend that we can ever know anything about the park as a whole. If, however, we can say that we are interested in monitoring the park road because that is where any potential impact will be most pronounced and the area where we have any hope of taking meaningful management actions, then we are justified in reducing our scope to the road corridor. Whether this is truly our desire or one forced on us by practical considerations does not matter. What is important is that we understand the ramifications of our choices.

3.4 Number of sampling locations

Once the scope of inference is established for Denali LTEM (e.g., entire park or road corridor) then we can use concepts from sampling theory to determine an appropriate number of locations to sample. Of course, practical considerations may once again force us to select fewer locations, but the exercise would nonetheless be worthwhile. In determining the number of locations to sample, we will need to consider the temporal intensity as there are financial and physical limits to how much can be done in one summer. Considering the small mammal monitoring scenarios described above, we can once again define the two extremes of a spectrum. At one extreme we can sample as many locations as possible with the minimum sampling scenario of two primary and two secondary sampling events. At the other extreme we can sample fewer locations with the maximum sampling scenario of five primary and 12 secondary sampling events. These two extremes represent extensive and intensive monitoring strategies, respectively.

We envision a workable strategy to be somewhere in the middle, perhaps with different temporal intensities at different locations. In section 5, we present a framework for Denali LTEM that incorporates these ideas.

4. Denali LTEM

As mentioned earlier, some of the issues raised here will need to be resolved for Denali LTEM as a whole, not just for the small mammal component. The question regarding the scope of inference is critical in determining the appropriate course to take in scaling up the monitoring beyond Rock Creek. Do we want to make a statement regarding the status of the entire park or can we limit our attention to the heavily used road corridor? Can we perform monitoring activities within sight of the park road? How can we access the sampling locations wherever they may be? These are questions that need to be addressed.

4.1 Commonality of LTEM projects

To conduct a coherent and integrated monitoring program, there needs to be some commonality between the various components. This is achieved through colocation of study sites. Rather than each project selecting its own sampling locations, integrated sites should be selected that will include subplots for monitoring small mammals, vegetation, meteorology, etc.

4.2 Making decisions

So how do we determine the optimal design for the scaling up of Denali LTEM? First and foremost we must nail down the goals of such a monitoring project. With those clearly defined, we can undertake a cost-benefit analysis to consider some of the specific design considerations outlined in this report. For small mammal monitoring, these include the number of primary and secondary sampling events and sampling locations. It is important to recognize that access will likely play a large part in determining the design. We have typically held that the cost of getting to and setting up a field site is so high that we should make that most of it once we are there. This translates into three or four sampling grids and a large number of secondary sampling events. Similar cost-benefit analyses can be conducted for other projects.

5. Proposed Monitoring Framework

As a starting point for discussion of a complete monitoring program for Denali NPP, we present a monitoring framework that brings together much of what has been discussed. This is not intended to be a highly polished protocol, but rather a first volley in what is sure to be a lively exchange. This framework begins with two assumptions: (1) monitoring will be conducted along the road corridor only and (2) monitoring can be conducted within sight of the park road. We believe that limiting our attention to the road corridor is appropriate given that most visitor impact occurs here and would more than likely be the location for any management actions based on perceived monitoring trends. Defining our study area as the road corridor avoids access problems inherent with remote areas of the park, allowing us to take a truly representative sample of our reduced study area. We also believe that we must have access to the entire road corridor for monitoring, whether or not potential sampling locations can be viewed from the road. It is precisely because these areas can be viewed from the road and are readily accessible that necessitates their inclusion. It is here that some forms of impact can be expected and should be monitored.

5.1 Locating monitoring sites

Using a two-stage sample design, we begin by selecting 12 monitoring sites along a transect that follows the park road and extends another 25 km past the west end of the road. The first stage is to select 12 drainages along the transect by defining four strata and randomly selecting three drainages from each to insure coverage along the entire road. Strata might be defined as (1) the park entrance to Teklanika campground, (2) Teklanika campground to West Fork of the Toklat, (3) West Fork of the Toklat to Wonder Lake, and (4) west of Wonder Lake. Drainages would be identified (approximately 25 drainages cross the park road) with three selected at random from each strata. Figure 3 shows a map of a possible sample of 12 drainages from the 25 possible. The second stage is to randomly place a 500 m by 500 m monitoring site within 5 km either side of the drainage and the road. In this way, each monitoring site is associated with a drainage for aquatic monitoring, although a water body does not necessarily flow through each site.

5.2 Components within a monitoring site

Subplots will be established within each monitoring site for small mammal, vegetation, avian point counts, hares/furbearers, and meteorology monitoring as depicted in Figure 4. There will be two or three small mammal sampling grids per monitoring site. The number of vegetation plots and point count stations will be determined by the respective principal investigators. There will be a single meteorological station set up in the center of the site and the entire monitoring site will be used to monitor hares and furbearers. Aquatic monitoring will take place at the associated river. This description of a monitoring site provides for the necessary colocation described in section 4.1, extending beyond small mammal monitoring to the totality of Denali LTEM.

5.3 Rotating monitoring intensities

In any given year, some number of the monitoring sites will be identified for intensive monitoring, others will receive a non-intensive effort, while still others potentially are not monitored at all. For small mammal monitoring, each intensive monitoring site will have five primary sampling events, while the non-intensive monitoring sites will have one. Similar distinctions can be made for the other monitoring components. With this rotating monitoring scheme, each site will be intensively monitored periodically with reduced monitoring during the intervening years in a combination of intensive and extensive coverage.

How often a location is intensively monitored and whether some sites will need to excluded from monitoring each year depends on what needs to be done and how much time is required. For example, consider the small mammal monitoring effort just outlined. A primary sampling event consists of 12 secondary sampling events for a sampling period of four days. Factor in two days for set-up, take-down, and transportation and another for recovery, we can expect to conduct one primary sampling event per week with a single crew. An intensive site will receive five of these primary events throughout the summer, while a non-intensive site receives only one. We can optimistically expect to have a field season of 12 weeks in Denali NPP, which means a single crew cannot visit all 12 sites in a summer if even one of them is to be monitored intensively. The best scenario for a single crew in one field season is to intensively monitor one site (5 weeks) and non-intensively monitor seven sites (7 weeks), while the remaining four sites are not visited that year. Another workable schedule is to intensively monitor two sites (10 weeks) and non-intensively monitor two sites (2 weeks), leaving eight sights not monitored in any given year. The only other alternatives would involve adding a second crew, allowing up to 24 primary sampling events per year. This would permit us to intensively monitor three sites (15 events) and non-intensively monitor the remaining nine (9 events) so that all sites are visited at least once each year.

We will further explore the first scenario to see how it might be carried out. With one intensive site and 7 non-intensive sites per year, we could create a 12-year cycle where every site is visited two out of every three years. There are several way that monitoring intensities can be allocated to sites by year, but we will outline one that attempts to maximize our ability to make comparisons between sites. The 12 sites are grouped into three cohorts of four sites each with each cohort containing a site chosen at random from each of the four strata. Every year one cohort is not visited and one cohort is visited once (non-intensive). In the third cohort, one site is intensively monitored, while the other three are visited once. This is repeated each year for 12 years and the cycle begins again.

If we consider 12 sites numbered 1 through 12, then we can say sites 1 through 4 are one cohort, sites 5 through 8 are another, and sites 9 through 12 are the last. This table lays out the succession of sampling intensities for each site in a 12 year cycle.

Site	Cohort	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12
1	A	■		▒	▒		▒	▒		▒	▒		▒
2	A	▒		▒	■		▒	▒		▒	▒		▒
3	A	▒		▒	▒		▒	■		▒	▒		▒
4	A	▒		▒	▒		▒	▒		▒	■		▒
5	B	▒	■		▒	▒		▒	▒		▒	▒	
6	B	▒	▒		▒	■		▒	▒		▒	▒	
7	B	▒	▒		▒	▒		▒	■		▒	▒	
8	B	▒	▒		▒	▒		▒	▒		▒	■	
9	C		▒	■		▒	▒		▒	▒		▒	▒
10	C		▒	▒		▒	■		▒	▒		▒	▒
11	C		▒	▒		▒	▒		▒	■		▒	▒
12	C		▒	▒		▒	▒		▒	▒		▒	■

■	Intensive monitoring
▒	Non-intensive monitoring
	No monitoring

With this scheme, every site is monitored two out of every three years for a total of eight visits in 12 years, one of which is an intensive monitoring visit. The monitoring sites are randomly assigned to cohorts, providing the required randomization. Pairwise comparisons can be made between sites in the same cohort for all eight years they were monitored. Pairwise comparisons can also be made between any two cohorts for four of the eight years they were monitored.

Another possibility considered is to define three strata instead of four, and use strata as the cohorts. Two complete strata would be monitored each summer, minimizing the amount of travel required between sites in two out of the three years. In the third year when the easternmost and westernmost strata are monitored, travel requirements would be increased, resulting in the need for a similar increase in the budget.

Similar schedules can be created for other possible scenarios that will provide for maximum utility in the data. The use of two field crews warrants consideration as it would have the two-fold benefit of being able to intensively monitor more than one site per year and to visit each site annually.

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7. Figures

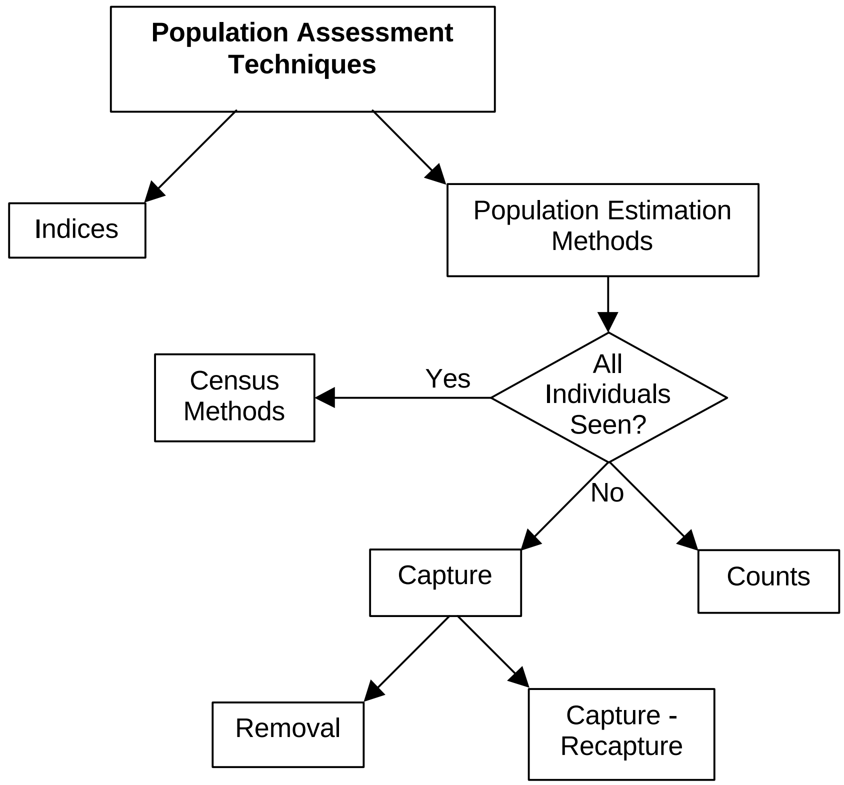

Figure 1: Relationship of several population assessment techniques (adapted from Lancia *et al*, 1994). See text for discussion.

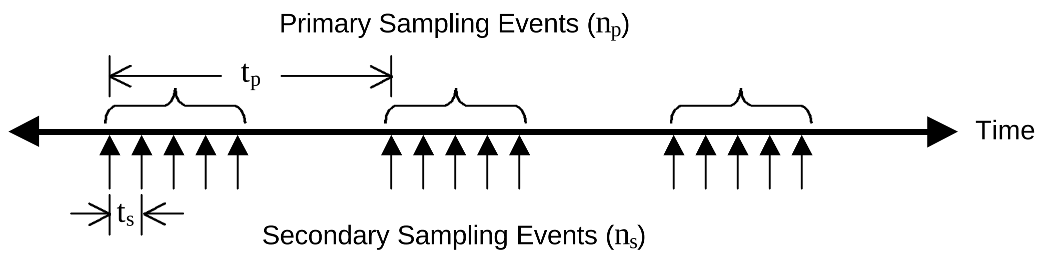

Figure 2: Generalized capture-recapture timeline. A monitoring design using capture-recapture methods involves four critical elements depicted here: total number of primary sampling events (n_p), time interval between primary sampling events (t_p), total number of secondary sampling events within each primary event (n_s), and time interval between secondary sampling events within each primary event (t_s).

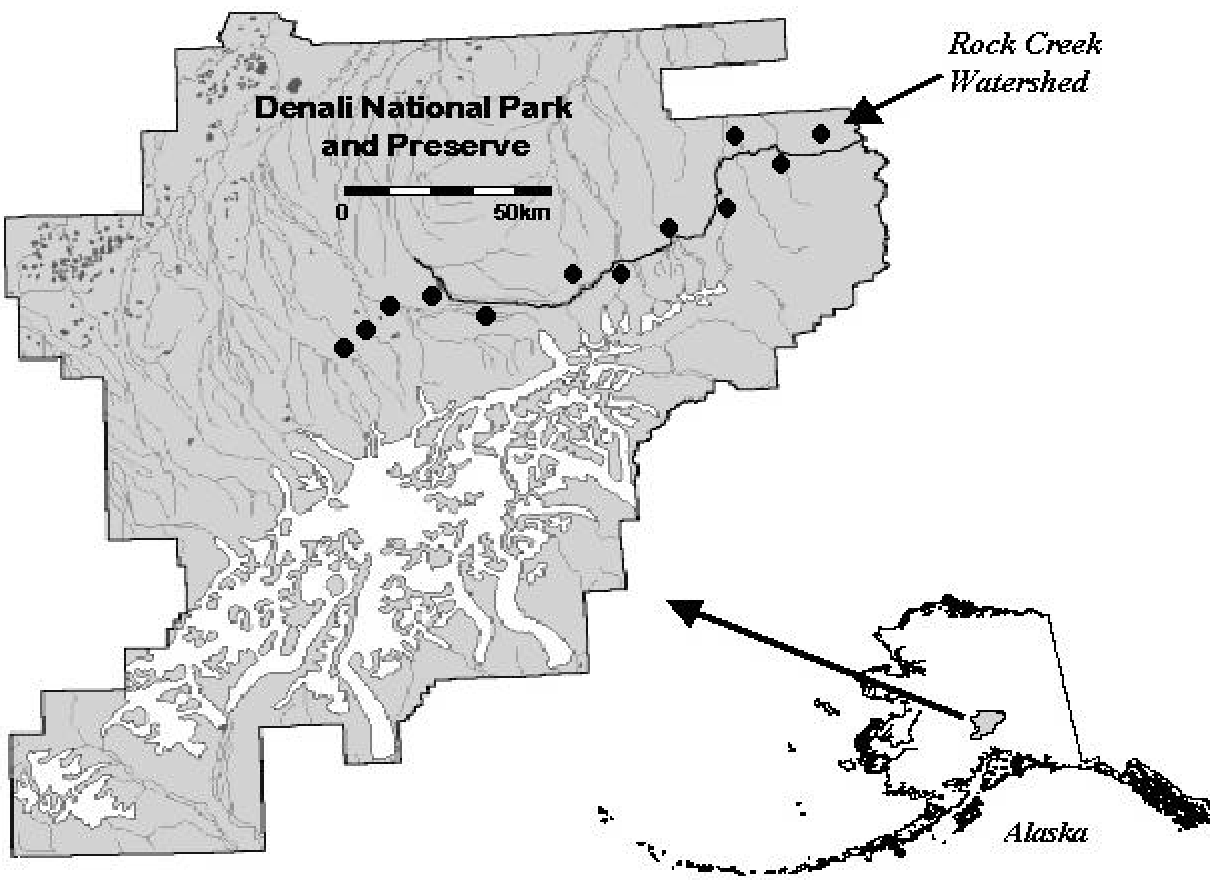

Figure 3: Possible selection of 12 monitoring sites along the road corridor of Denali NPP. Each site contains components for small mammal, avian point count, vegetation, furbearers, meteorology, and aquatic monitoring.

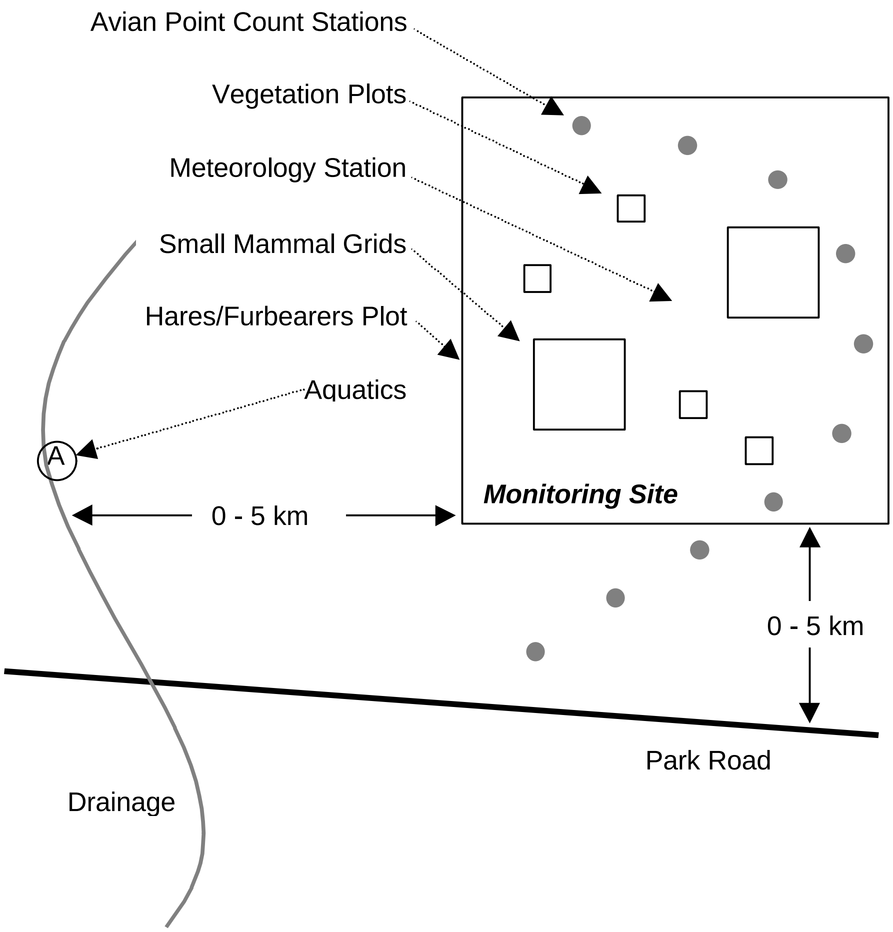

Figure 4: Monitoring site schematic. Each site is 25 ha in size (500 m by 500 m) and contains subplots for monitoring small mammals, vegetation, hares/furbearers, birds, and weather, and is associated with a nearby drainage where aquatic monitoring takes place. Twelve such sites will be selected along the park road transect.