Black Bear Mark-Recapture Study Using Remote Cameras

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An Abstract of a Thesis

Submitted in Partial Fulfillment of the

Requirements for the Degree of

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in Biological Sciences

Central Connecticut State University

New Britain, Connecticut

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ABSTRACT

The number of encounters between black bears (*Ursus americanus)* and people is increasing in Connecticut. This increase necessitates management planning, which cannot occur until the actual population size of black bears has been determined. A mark-recapture study may be useful; however, current research suggests that bears may become either trap happy or trap shy, which can skew population estimates.

One approach to produce a more efficient population estimate is to use different modes of capture for the first and second sampling. For this study I used Moultrie Feeders Game Cam II cameras as the mode of "recapture" of bears that had been trapped for the first sampling. I collected 124 black bear photographs; ninety-six percent (119/124) were usable photos (bears could be identified as either tagged or not tagged). These numbers were inserted into the Peterson estimate to determine an estimate of the total population of black bears in my study area.

In order to determine whether multiple sampling of some individuals but not others biased the results, I compared three methods of estimating population size that differ in the number of multiple samples. These methods were compared to the estimate produced by DEP trapping efforts for the summer of 2003.

After comparing the state trapping data with the number of photographs of marked and unmarked bears caught in the second capture using the cameras as the mode

of recapture, it appeared that the bears were ‘trap happy’ but not ‘camera happy’. My camera based method of “recapture” resulted in a higher calculated population estimate than was produced using trap-re-trap data only. Based on my findings, I believe the most accurate population estimate of black bears in the study area is 83 bears.

The cameras were a viable, and possibly preferable, alternative to the traditional mark-recapture study, because the ability to move the cameras quickly and easily to a new station after a bear visit allowed me to sample a large number of locations at minimal cost and time, while reducing the bias associated with ‘trap-happy’ bears.

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INTRODUCTION

The black bear (*Ursus americanus*) population in the state of Connecticut has increased dramatically in recent years. In 1999 the CT Department of Environmental Protection estimated the total number of bears in the state to be between 30-60 bears (CT DEP 1999). In little over 4 years, the present DEP estimate of resident black bears has increased to 150-200 (Freeman 2004). Up until now, wildlife biologists in Connecticut have depended upon live trapping and random encounter rates to produce population estimates. Because traps just sample a portion of the total population, they do not directly show the true population size. They instead give the DEP an idea of how many new bears they are trapping each year. As the number of bears and human/bear encounters increase dramatically in the state (CT DEP 2004a), biologists are interested in developing other censusing techniques that may yield a more accurate estimate of the total number of bears in Connecticut. With this information, the CT DEP will be able to develop strategies to manage the population and the habitat that they require to survive.

Wildlife management strategies will only be effective if they are based on accurate population estimates, as these strategies must change in response to changes in population size. Some management policies are established in response to species at risk due to declining numbers. Policies may include captive breeding programs, special protections for endangered species, and land-use plans, such as the preservation of open space, wildlife corridors, and protection of critical habitat (Maryland Department of Natural Resources 2003). Different strategies must be implemented when a species poses a risk to its habitat or other species due to its increasing numbers. Such strategies may include controlled hunts, instituting a hunting season (Maryland Department of Natural Resources 2003), removal of a species, rehabilitation, trap and transfer, constructing physical barriers to dispersal, and immunocontraception (Maryland Department of Natural Resources 2004).

Throughout the development and implementation of management strategies, wildlife managers must continue to monitor the population size to determine whether the strategy is working. One standard population censusing method is the mark-recapture study. In a traditional mark-recapture study, a random sample of individuals is captured, marked, and released. Some time later, a second capture is conducted in which another random sample is taken from the same population. The second catch will include a certain percentage of tagged animals. The proportion of recaptures (tagged animals) to the total number of captures in the second round should be the same as the proportion initially marked to the total population (Jackson 1939). This technique is called the Petersen estimate and the equation for calculating N, the total population size, is as follows:

$$\frac{\text{Total marked}}{\text{Total population size, N}} = \frac{\text{Number of marked caught in second capture}}{\text{Total marked and unmarked caught in second capture}}$$

therefore,

$$N = \frac{\text{Total marked x Total marked and unmarked caught in second capture}}{\text{Number of marked caught in second capture}}$$

The Petersen estimate should only be used when several assumptions are true “or approximately true” (Seber 1970):

“(a) The population size *N* remains constant
(b) All animals have the same probability of being caught in the first sample
(c) Catching and tagging do not affect future catchability
(d) The second sample is a simple random sample
(e) Animals do not lose their tags
(f) All tags are recognized and reported on recovery in the second sample.”

According to Seber (1970), slight departures from some of these assumptions may not significantly impact the validity of the estimate. For instance, a change in N due to mortality may have a minimal impact if the rate of mortality is the same for tagged and untagged animals. In addition, if immigration/emigration rates are equal for tagged and untagged animals, the estimate will still be accurate.

However, even slight departures from assumptions (b), (c), and (d) could significantly bias the resulting estimate. If either assumption (b) or (c) is false, assumption (d) will in all likelihood be false (Seber 1970). For instance, if some animals are more catchable than others, then the tagged animals (caught in the first capture) are more likely to be caught in the second capture. If, on the other hand, assumption (b) is true, but the act of catching and tagging impacts future catchability by creating ‘trap happy’ or ‘trap shy’ individuals, then the second capture will be non-random. In fact, trapping can significantly influence the future catchability of certain individuals, as they may become ‘trap addicted’ or ‘trap shy’ because of behavioral response to capture (Chao 2001). Trap response will produce bias, and the direction will be dependent upon the type of response. For instance, ‘trap happy’ or ‘trap addicted’ responses will lead to negative bias in estimates of population size (Seber 1986). Negative bias results in an underestimation of the true population size. ‘Trap shy’ responses will lead to an overestimation of population size, as predominately untagged animals will be captured in the second round.

The Connecticut Department of Environmental Protection has been live trapping black bears using baited steel culvert traps. Because the experience of being trapped may be aversive and these traps cannot be hidden or disguised, black bears may learn to avoid the large steel culvert traps that are used to initially capture them, thereby negatively influencing the probability of recapture. On the other hand, bears attracted to the bait may become ‘trap happy’. Either response would violate assumption (c), that catching and tagging do not influence future catchability.

Although the Peterson estimate is said to be robust to small deviations from the 6 assumptions (Seber 1970), larger heterogeneity (inequality) among recapture probabilities for different individuals will yield a much greater variance around a point estimate of population size (Minta and Mangel 1989). For example, if there are 40 sightings of marked animals in the second sample, but they are all of the same animal, the estimate cannot be trusted. However, if the marked animals are each sighted an equal number of times, there is homogeneity (equality) among recaptures, and the estimate is more likely to be accurate. Minta and Mangel (1989) suggest that one approach to accommodate assumption (c) in order to produce a more efficient population estimate is to use different modes of capture for the first and second sampling. Many biometricians support the concept of using different sampling techniques for each sample in order to reduce bias (Buck and Thoits 1965, Minta and Mangel 1989, Seber 1970). According to Seber (1970), if the sources of selectivity (trapping method) in the two samples are independent, then trapping by the first method will not change probability of capture by the second, different, method.

Because ratios are used to calculate the total population size from data on recaptured individuals, photography is a legitimate method of "recapture". The same individual may be photographed more than once, but as long as both marked and unmarked individuals have an equal probability of being photographed, repeat sampling will not change the apparent ratio of marked to unmarked individuals.

Previous research suggests that remote sensing cameras can be a viable alternative to traditional wildlife sampling techniques. Cameras are an effective, non-invasive method for studying animal behavior, habitat use, and relative abundance, and for making population estimates (Bull et al. 1992, Carthew and Slater 1991, Foresman and Pearson 1998, Gysel and Davis 1956, Martorello et al. 2001). Some of the advantages of remote cameras over direct observation are that they can be used in areas that are difficult to access, and that they can be used to study animals such as bears and lions that are secretive, aggressive or otherwise hard to observe (Mace et al. 1994). Additionally, photographs allow definitive species identification, and even individual identification if animals are uniquely marked.

In many remote camera studies, it would be difficult, time consuming, and cost prohibitive to set remote cameras out in the field without using some type of bait or lure to attract the target species to the station. However, animals trapped in the first sampling may become ‘trap happy’ because of the reward of bait, and may be more likely to visit camera stations with bait than animals that do not have any experience with a bait reward. On the other hand, some animals may associate the bait with a negative experience of being trapped, and may avoid the bait even if there is no negative consequence related to the second, camera-sampling method. This reasoning leads us back to a violation of assumption (c).

Ideally, the bait used in the second sampling would be different than the bait used in the first sampling. In addition, the method in which the bait is presented to the animal could be different in the two sampling periods. Although the use of bait does have the potential to bias the results, using a different sampling method for the two samples will reduce the amount of bias.

Camera-based re-capture methods also carry the liability of an inability to determine how many times an unmarked individual has been photographed (in trap re-captures, unmarked individuals are marked as soon as they are trapped). Multiple visits by unmarked individuals can be reduced by having only enough bait to be consumed in one visit, and by moving cameras often.

However, the issue of multiple resampling of unmarked individuals exists even when no bait is used, if a camera station is located in a frequently visited area of an animal's home range, or if there is more than one camera station within the home range of a single individual.

Researchers in North Carolina developed and evaluated an inexpensive bait-triggered camera system as a technique to sight black bears in a capture-resight study (Martorello et al. 2001). The researchers modified an inexpensive camera by connecting low-stretch monofilament to the shutter mechanism and placing the camera in a customized housing, which consisted of an ammunition box with holes drilled in it for the camera lens and flash. The free end of the monofilament was attached to a bait. When an animal pulled on the bait, the monofilament was designed to break and trigger the camera to take a picture.

This study took place at two locations in North Carolina, and each site yielded a high percentage of bear photographs that researchers were able to use to calculate population size estimates for both locations (the bears were positioned correctly to view the head and neck regions where bears were marked). In order to increase the independence among sightings, the researchers spaced the cameras at least 1 km apart, and moved the cameras to new locations after between 5 and 12 days.

Martorello et al. (2001) used the Minta-Mangel model (Minta and Mangel 1989) to estimate the black bear population at one site, and Bailey's binomial model (Bailey 1951, Seber 1986) for the second site. The Minta-Mangel model requires that a marked bear be uniquely identifiable, as it uses resight frequencies of individually marked individuals to calculate the population estimate (Minta and Mangel 1989). On the other hand, the Bailey's binomial model does not require uniquely marked individuals, as it relies on simple proportions of unmarked and marked individuals (Seber 1986). Martorello et al. (2001) are unclear as to how they tackled the issue of multiple photographs of the same bear. Most likely this omission is because they obtained only one photograph per bear visit, and assumed that each visit was by a different bear. In addition, if there were multiple photographs of the same individual, Bailey's estimation model accounts for them (as long as marked and unmarked individuals were equally likely to be multiply photographed).

The information obtained in the Martorello et al. (2001) study was used as part of a mark-resight study, and was therefore subject to the general assumptions associated with the Peterson estimate. Although it is generally believed that the assumptions of population closure (lack of variations in N), independence among sightings, and equal probability of resighting marked and unmarked individuals are highly unlikely to ever be fully met in a mark-resight study (Arnason et al. 1991), the researchers believe that their design reduced biases related to these assumptions. To address violations of demographic closure, the researchers reduced the time span of the entire experiment from 12 months (which according to Martorello et al. (2001) is the time span between capture period and recapture end in traditional capture-recapture studies of black bears), to a total of 5 months. They attempted to reduce spatial dependence (dependence between stations) by spacing the cameras at least 1 km apart, and moved the cameras to new locations after between 5 and 15 days to reduce temporal dependence (dependence of sightings over time). Lastly, the researchers addressed the introduction of bias associated with differences in catchability. They believe that their study design was robust to these differences because they used different sampling methods for the two samples, and by doing so, the biases associated with the traps would most likely be independent of the biases associated with the cameras. They do, however, admit that the use of bait to attract animals to the camera stations during the resight portion of the study can influence the probability of resighting animals.

Martorello et al. (2001) obtained high percentages of usable bear pictures at a low cost, with minimal set up time, and with minimal training and supervision of staff responsible for setting up and monitoring stations.

Remote triggered cameras can also be used to survey other elusive carnivore species. Moruzzi et al. (2002) used a 35mm camera attached to a pressure plate located at a bait station. Several types of baits and lures were used to attract the target species to the stations. The purpose of the study was to identify relative densities of carnivore species at different sites, as well as habitat-use patterns; therefore, the researchers were not concerned with double counting individuals. The researchers do acknowledge that the techniques used in this study do not address the issue of possible bias associated with different levels of "attractiveness" of the stations for different species. Although the use of bait to attract the animals to the camera stations may have introduced some bias, the researchers believe that remote cameras may be the "best compromise for assessing carnivore distribution over relatively large areas" (Moruzzi et al. 2002, p. 381) because they offer definitive species identification and they detect species that are more rarely detected by radiotelemetry, smoked track plates, or track counts (ie., bobcat (*Lynx rufus*), fisher (*Martes pennanti*) and black-footed ferret (*Mustela nigripes*)).

A pilot study in Montana used a camera system to detect the presence of the American marten (*Martes Americana*, an important indicator species of mature old growth forests) (Jones and Raphael 1993). The goal of this study was to build and test an inexpensive camera system to replace the use of "inefficient" hair snares and track counts to determine the presence of martens.

Hair snares generally consist of placing barbed wire within a cubby that contains a lure or bait. The position of the barbed wire is dependent upon what the target species is. The objective is to make the animal pass the wire (either under, over or through) on its way to the bait or lure and leave some hair behind, trapped on the wire (Ministry of Environment, Lands, and Parks 1999).

The camera system developed by Jones and Raphael (1993) consisted of a camera attached to a mounting stake, with a monofilament line running from the trigger mechanism on the camera to the bait. When an animal pulled on the bait, the monofilament was broken and a picture was taken. The data collected from this study were used to determine the relative abundance of American martens at different sites based on detection rates. Because only relative abundance was being measured, the researchers were not concerned with the possibility that one individual animal might make multiple visits to the same station, or might visit more than one station at the same site, as long as the behavior of martens at the different sites was the same. However, it seems to me that if the species being researched (in this case, the marten) is territorial, the placement of stations would be critical and can't be controlled if the territory boundary locations aren't known, as they almost surely won't be. Stations at the center of the territory might get more visits than stations toward the edge; stations on an edge shared by 2 territories might get visits by occupants of both territories. Animals with more than one station in their territories might be counted more times than those with just one station in their territories. Jones and Raphael (1993, p. 14) do acknowledge "a relation probably exists between the location of the stations and detection success." They suggest that optimal length of running time and station spacing will influence detection success and will be different for different target species. This research was strictly a camera study and did not directly compare effectiveness of cameras to hair snares or track plates.

The relationship between the placement of stations and territorial or home range boundaries cannot be ignored, and should be a concern for all trapping and especially camera studies. Bears have large home ranges, and the home ranges of different individuals overlap.

According to a study conducted by Foresman and Pearson (1998), cameras may not only be appropriate, but may be preferred to other forms of animal detection techniques. Foresman and Pearson compared dual-sensor remote cameras to soot-coated track plates for effectiveness and accuracy of identifications of forest predators.

The researchers constructed track plates based on the protocol established by Zielinski and Kucera (1995) with a few minor modifications. Both the open and closed track plate setup consist of a carbon-sooted aluminum plate placed in an open-ended plywood box placed horizontally on the ground and anchored to a tree trunk. The open track plate creates a “negative” impression when the underlying plate surface is revealed after an animal steps on the plate and removes the soot (Zielinski and Kucera 1995). The closed track plate differs from the open track plate in that it allows the researcher to collect a “positive” track impression with the addition of a sheet of tacky white paper placed at the back end of the aluminum plate. Once the animal enters the box, the soot adheres to the animal’s foot. When the animal steps to the rear of the box the soot is transferred to the white paper. The track plates were baited with chicken.

The cameras used for this study were dual sensor (infrared heat and motion monitoring) that detect motion and changes in ambient temperature (Zielinski and Kucera 1995). The cameras were located 0.8 km apart, but the article does not explain the actual camera set-up. Deer quarters were suspended between the trees (animals could not get to them) to serve as “non-rewarding” bait and the sets were scented with commercial trapping lures (Foresman and Pearson 1998).

Foresman and Pearson (1998) compared open and closed track plates and remote-sensor cameras by performance in 5 categories: latency to detection, species detection, ease of identification, effort in implementation, and cost. They found that cameras detected more target species (American marten, fisher, wolverine (*Gulo gulo*), and lynx (*Lynx lynx*)), required less work to implement, and provided a simpler means of species identification.

There are several different types of remote camera systems available to researchers, and they vary greatly in the type of equipment, methods used and price. The equipment can be assembled by hand by the researcher or can be purchased pre-assembled by a manufacturer that specializes in remote photography equipment. Systems can range in price from $50 to greater than $5,000/unit (Cutler and Swann 1999). Generally, the choice of equipment is determined by the available funding and to some extent by the type of research question or animal being studied. Although there are many types of remote cameras on the market that contain all the features that one would need, they tend to be very expensive, therefore many researchers have opted to construct their own camera systems (Danielson et al. 1996, Goetz 1981, Jones and Raphael 1993, Moruzzi et al. 2002).

One of the drawbacks of a self-constructed camera set-up is that in most instances the camera must be reset by the researcher after each triggering event. If the picture is of a non-targeted animal or does not show the information that the researcher is looking for, the researcher must set up the camera again and wait to see if the target animal returns. This also means that there is a down time between a triggering event and the time the researcher revisits the site. The pre-assembled remote cameras allow the researcher to take multiple pictures between visits. Most pre-assembled set-ups allow the user to time and date stamp the film as the picture is being taken. This stamping is helpful to determine the time of day, duration of a visit, and the time elapsed between visits.

The purpose of this study was to determine the proportion of tagged vs. non-tagged bears in Connecticut. Therefore it was imperative to be able to establish whether the bear being photographed was tagged or not. Double counting of tagged bears can be tracked if individuals can be identified from the tag number. The best assurance that a bear can be identified by tag number is to obtain multiple exposures. Time and date stamps on the exposures can assist the researcher in determining whether multiple pictures of a bear were taken during one visit or on different occasions. Consequently, for the purposes of this study, I chose to purchase a pre-assembled camera system that allows for multiple exposures and the ability to time and date stamp the pictures.

From the photographs I obtained the number of tagged and non-tagged bears that passed by my cameras. These numbers were inserted into the Peterson estimate to calculate an estimate of the total population of black bears in my study area, which included most of the areas in which bears are believed to live in Connecticut. This information will be relayed to the DEP so that they will be able to use it to guide management strategies. It will also provide the DEP with a baseline population estimate for comparisons in future years to determine the health and status of the black bear population in Connecticut.

RESEARCH METHODS

STUDY AREA

The study was conducted in northwestern Connecticut in Tunxis, American Legion, and People's State Forests and adjacent land connecting these forests. The study area was approximately 52.6 sq km. Tunxis State Forest comprises approximately 37 sq km and consists of mixed hardwood, softwood-hardwood, and hemlock (*Tsuga canadensis*) forest with streams and wetlands, and some smaller areas of extensive hemlock or white pine (*Pinus albicaulis*) with mountain laurel (*Kalmia latifolia*) understory (CT DEP 2004 b). People's State Forest is approximately 12.1 sq km and consists of extensive areas of steep rocky ridge land dominated by chestnut oak (*Quercus prinus*) with a thick understory of mountain laurel. There are four large areas where all trees were cut between 2 and 8 years ago, which have thick stands of regenerative growth of red maple (*Acer rubrum*), black birch (*Betula lenta*), and white pine (Landgraf 2004). American Legion State Forest is approximately 3.2 sq km, with similar vegetation and land cover to People's State Forest.

Camera station sites were limited to state and DEP owned properties. I used information provided by the Connecticut Department of Environmental Protection on the location of their bear traps, and the locations of home ranges of radio collared female bears, over the last two years (from the time trapping began to present), to determine my study area location. Male bears were also trapped and tagged, but are not typically radio collared, as their home ranges are too large to be able to effectively track them with telemetry. I located my camera stations in the area surrounding the trap sites and telemetry locations, as an attempt to reduce any bias associated with areas where no trapping had occurred, which might have little likelihood of resighting tagged bears. The CT DEP concentrated its trapping efforts in the northwestern portions of Connecticut because it is believed that this is where the majority of bears in the state can be found. Because my sampling only occurred in a portion of the state, it must be acknowledged that the calculated estimate only reflects the number of bears in the sample area, and the actual number of bears in the state may be higher if there are bears located outside the study area.

All camera stations were located within the state forest properties along limited access roads (i.e. locked gate or un-maintained two-track road). Stations were located at least 150 m from the road and at least 1 km from the next nearest station to reduce dependence between stations (Jones and Raphael 1993, Moruzzi et al. 2002). Black bear home ranges in Connecticut are approx. 15 - 50 km^2 for females, and 31 – 155 km^2 for males (CT DEP 1999). Several bears (both male and female) have overlapping home ranges. Hirsch et al. (1999) suggest that extensive home range overlap is quite common. Samson and Huot (2001, p 637) found that an area that “contained important food resources, was used intensively by more than one bear, often simultaneously.”

For this study, I used a map of six radio-collared bears’ home ranges (Figure 1) and tried to place cameras in the different known home ranges, as well as in some apparently suitable habitat where radio-collared females had not been tracked. In addition, the bait was never replaced once a bear had visited, and cameras were frequently moved to new locations.

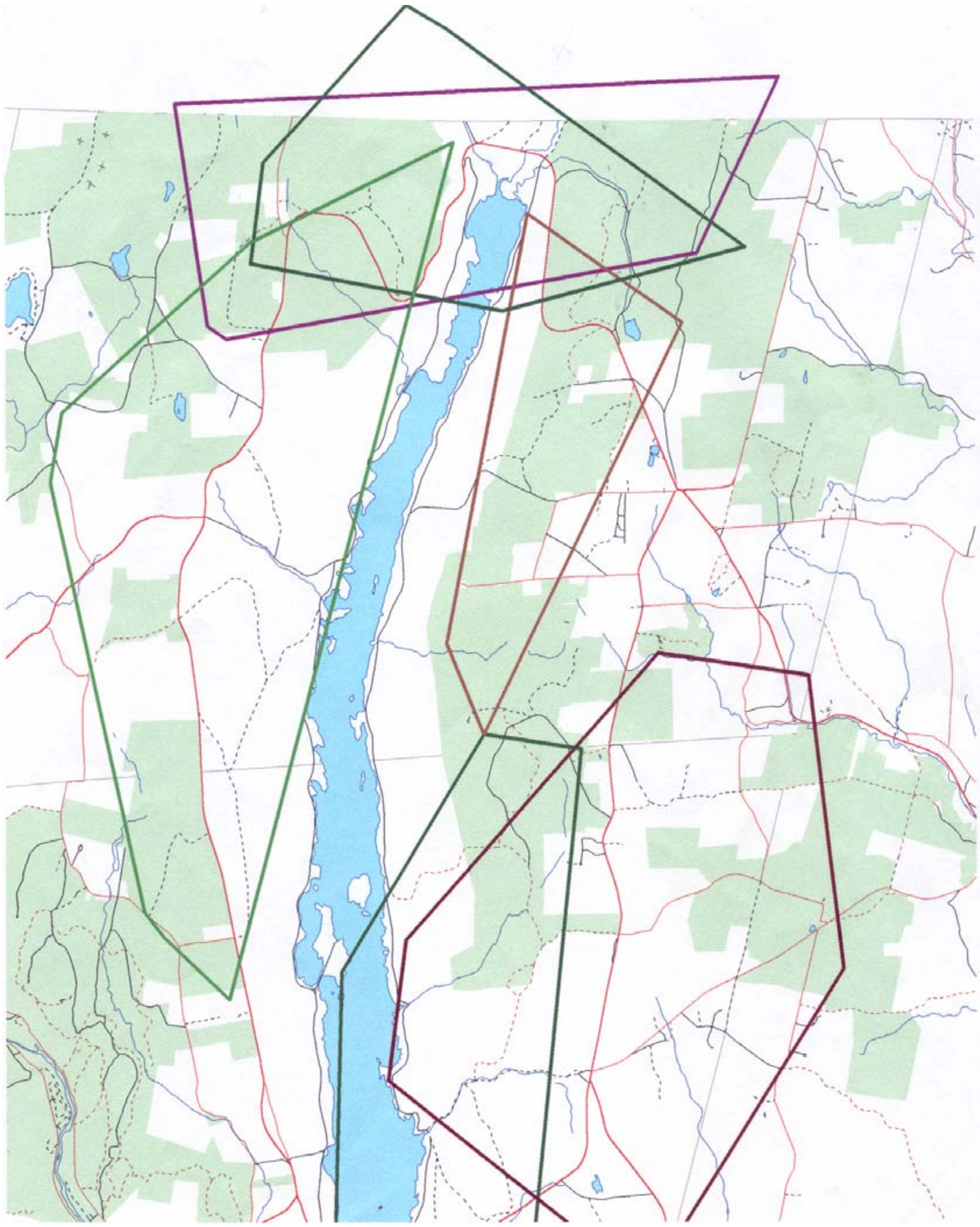

Figure 1. Map of home ranges of six radio-collared black bears.

Sites were evaluated for suitability based on the presence of suitable habitat for bears (food availability, access to water, steepness of slope, etc.) and for the following logistical limitations. Tree dbh and density were considerations because cameras could not be mounted on very small trees, and extensive ground cover or tree density would not allow for a clear line of site between camera and bait. Accessibility was also important. Therefore, the coverage of the area was not uniform, and I had no cameras near some DEP trap sites. A total of 30 different camera sites were used (Figure 2).

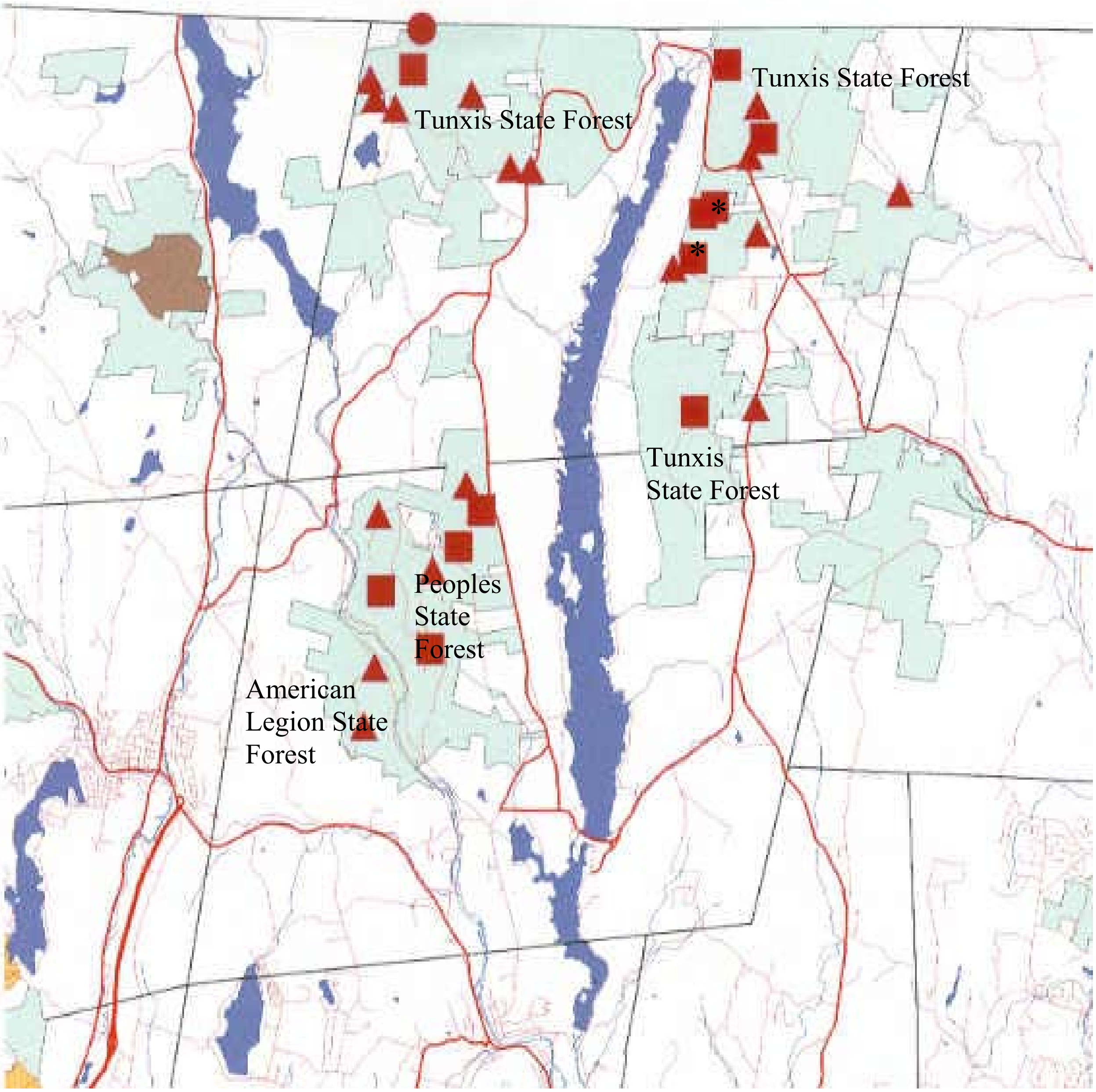

Figure 2. Camera locations and animals photographed. Circle = bear and moose, square = bear, triangle = no bears photographed.
* There are two sites (each with bear sightings) at these locations.

TYPE OF CAMERA

I used Moultrie Feeders Game Cam II cameras, manufactured by Moultrie Feeders, a division of EBSCO Industries, Inc. The Game Cam II is a dual sensor (infrared heat and motion monitoring) camera system that detects motion and changes in ambient temperature. It is a pre-assembled unit that contains a 35mm camera mounted in an ABS weatherproof plastic housing. The camera has an auto-focus function, with a focus range of 0.33 m-infinity (1.5-8.5 meters was recommended for the best results). It had a built-in automatic flash, and date and time imprinting powered by an internal battery. The camera was hard wired with battery terminal connections to accept a 6-volt alkaline spring top battery. The large battery was necessary, as the camera and sensor were continuously on. The camera had an automatic rewind feature, but could be manually rewound mid-roll when necessary. The camera had a switch that allowed me to choose either a 15 second or a 6 minute delay between pictures. The 6 minute delay time helps conserve film. The camera had an AIM light that could be turned on to assist the user during camera set-up. The camera also has two power mode options. The high power mode continuously charges the flash so it is immediately ready to snap a photo at night. The low power mode “puts the battery to sleep” until an animal is detected. The low power mode conserves battery life, thus doubling the life of the battery. I used the high power mode because I wanted the flash to be ready at all times.

The camera housing has an eyelet in a metal plate on either side of the box on the back of the unit for mounting. I used a small hole drilled through the camera box latch to insert a lock to secure the camera inside the box.

CAMERA AND BAIT STATION SET-UP

I designed the bait stations using 1.5 cm mesh, 19 gauge, galvanized and vinyl coated hardware cloth cut into 30 cm by 50 cm strips. The strips were bent in half to make a cage-like structure. I secured the two open sides of the cage by twisting a small piece of 16 gauge wire around the open ends approximately halfway between the top and bottom of the cage. I then filled the cage with day old pastries (cupcakes, turnovers, donuts, frosted cakes, fruit pies, tarts, and cookies) that were donated by a local supermarket. This is similar to the bait used by the DEP in bear traps (day old donuts and bagels). The top of the cage was secured by wrapping a 10 cm piece of 16 gauge wire around the opening and twisting it tight at one end. The bait cage was secured to the tree approximately 1.52 m above the ground by nailing a 5 cm 6d nail into the tree and wrapping the free end of the 16 gauge wire around the nail.

The camera was positioned in a tree approximately 1.7 m away from the bait tree at a height of approximately 1.2 m above ground level.

The camera was attached to the tree using 1.5 m nylon ratchet tie-downs. The tie downs had metal s-hooks at each end to loop through the eyelets on each side of the camera box. The camera was secured to the tree using a cable and a combination lock inserted through a hole in the camera box latch.

Figure 3. Camera and bait station set up

The cameras were set up to time and date stamp the pictures with the day-hour-minute (the hour used the 24 hour clock).

I initially set the cameras on the 15-second delay, as I was unsure of how quickly the bears would take the bait and leave the site. After the first few station checks, I found that the majority of the photographs I got were at the least, minutes apart, and in most cases I did not run out of film between visits to the station. Therefore, for the remainder of the study I kept the cameras on the 15-second delay.

I used 6-volt alkaline spring top batteries and 200 speed 24 exposure Kodak film. The cameras were equipped with an automatic flash, so that I was able to take photographs when there was not enough light available (at night, rainy day, dark forest). The batteries were changed approximately every 17 days as the camera specifications indicate that battery life is approximately 20 days.

DATA COLLECTION

I had 4 cameras. I first set out the cameras on 5 June 2003, and removed the last camera on 25 August 2003. I did not visit the camera stations between 1 August and 14 August, though 3 cameras were out photographing at stations during this period. Due to a high rate of camera failure, there were often fewer than 4 operable cameras out at a given time. I checked the stations on Mondays and Thursdays. On my first visit back to the station, the bait cages were checked to see if the bait was still there, and whether the cage had been broken or destroyed. If the cage still contained the bait, the cameras remained at this location until the next visit. Before leaving the site I checked to ensure that the cameras were still secured and working properly. If the bait was gone, but there was no evidence of a bear visit (cage still intact in tree), then the bait was replaced and the camera checked to see if there were still enough exposures left on the film (over 10 exposures left; if not, film was changed). If there was evidence of a bear visit (bait cage mangled, destroyed or gone), the camera was checked to ensure that there were pictures taken, the film was removed for processing, and the camera was moved to a new location. If the cameras remained at a station after one visit because of no activity, or no pictures taken, they were then removed on the second visit regardless of activity.

The film was dropped off for developing at a local 1-hour processor to reduce turn-around time. This enabled me to determine if there was a problem with a camera set before the next visit so that I could make adjustments or remove the camera for repairs in a timely fashion.

DATA ANALYSIS

I placed the pictures in an album that had space in the margins to write in the camera number and location. The pictures were organized by location and time taken. The number of photographs of tagged vs. non-tagged bears were determined by looking at the ears of the bears in the photographs. As the DEP was continuing to mark bears during the time of this study, bears marked during the study were counted as unmarked. This practice eliminated the possibility of counting the same bear as both untagged and tagged during this study. Bears marked during the study period had a tag labeled 03 and a unique identifier, and the tags were white. In the previous two years, bears were marked with either yellow (2001) or orange (2002) tags labeled with the corresponding year and individual identifiers. The DEP had marked a total of 37 bears in Connecticut from 10 September 2001 to 5 June 2003; two of these are known to have died before my study began, and one died after my study concluded.

The numbers of tagged and non-tagged bears photographed were then used to calculate a population estimate (N) using the Petersen estimate. The total number of marked bears used in these equations was 35, the number of bears that the Department of Environmental Protection had marked up to the beginning of this study, that were not known to have died before my study began.

A number of different methods were used to estimate the proportion of marked bears in the population. The camera "recapture" method used in this study differs from typical mark-recapture sampling in two important ways: 1) the same individual bear may be "sampled" multiple times. Multiple sampling should not affect the apparent proportion of marked vs. unmarked individuals in the population, as long as marked and unmarked individuals are equally likely to be sampled multiple times. 2) the use of bait at both the DEP traps and the camera sites may produce "trap happy" individuals. I expected this might particularly be the case at the camera sites, where there are no negative consequences of being "caught".

In order to determine the extent to which multiple sampling of some individuals but not others might bias the results, I compared three methods of estimating population size that differ in the number of multiple samples. In the first method, I counted every photograph in which a bear appeared. In the second method, a bear was counted only once for each unbroken series of photographs in which it appeared (where the duration of the series was less than 24 hours). In the third method, bears that appear identical on the photographs taken from the same camera were re-counted only in photographs taken 24 hours apart (although bears will probably entirely consume a bait during a single visit, if the same bear returned to the same bait, it was probably most likely to do so on the same day).

I also calculated two estimates based on data from DEP trapping efforts for the period of 5 June 2003 to 25 August 2003. Using these trapping data, each bear, marked or unmarked, could be counted only once because each bear was individually identifiable (marked bears each had a unique tag number, and unmarked bears were similarly marked before being released). In method 4, I counted every capture and every recapture regardless of the number of times an individual bear was recaptured. In method 5, on the other hand, only one recapture was counted for each individual bear.

RESULTS

The Connecticut Department of Environmental Protection began trapping black bears in the spring of 2001 and continued to trap through the fall of 2003. As of 5 June 2003 the DEP had trapped a total of 37 different bears (27 males and 10 females; of these, two died before my study began, and one after). Bears were trapped using large steel culvert traps baited with old donuts and pastries. Bears caught in the traps were tranquilized and each bear was tagged with two square 2” x 2” plastic tags (one in each ear, with one facing the front of the bear and one facing the rear). The tags were labeled with a permanent black marker with a unique identifier (in most cases this was a sequential number beginning with the first bear captured in a given year, followed by the two digit year). All females (except one) were fitted with radio collars; thus, 9 females had radio collars.

Figure 4. Photograph of DEP personnel tagging a captured bear

Camera stations were set up and monitored from 5 June 2003 to 25 August 2003. Trapping did continue throughout this study period, however, only those bears trapped prior to June 5 were considered tagged for the purpose of this study.

My sampling included a total of 82 censusing days, with 1-4 cameras out on each day. However on occasion cameras were found to not be functioning upon the return check. In all cases when the cameras were found to be non-functioning, the cameras did not take any photos between set up and check, therefore these cameras could be considered non-functioning for the duration of that specific time in the field. Therefore, the actual number of camera-days (days with cameras out multiplied by the number of functioning cameras) was 202. In actuality, the number of camera days could have been as high as 328 (82 days x 4 cameras), however, there were many occasions when one or more cameras were not set at stations because they were being serviced. This translates to only 62% (202/328) of the available camera-days being used. The majority of camera malfunctions were related to either the remote sensor mechanism not triggering properly, or the camera not responding to the trigger. It was unclear whether the fault was in the wiring or in the camera itself. The cameras were not repaired, but were instead sent back to the manufacturer for replacement. This meant that there was often a two to three week lag between taking the camera out of the field, and installing a new camera. A total of 30 different camera sites were used; at 15 of these sites cameras were out for 7 days, 10 sites had cameras for 4 days, 2 for 3 days, and 3 for 17 days (including the 14 days in August that I did not check the stations).

Latency to detection (LTD) (the number of days to the first exposure of the target species) ranged from 0 days to no bears photographed during the 7 days that a camera was in place ($\bar{x} = 3.23$, $\sigma = 2.68$, $n = 30$). On three occasions, black bears were photographed at the bait station on the same day that the station was set.

Three hundred and ten photographs were collected. Sixty percent (186/310) were of non-target species or showed no animals. Of the 186, fifty-nine percent (109/186) were raccoon, forty percent (75/186) had no animal present in the photo, and one percent (2/186) was moose. Forty percent (124/310) were photographs of black bears. Of the 124 black bear photographs, ninety-six percent (119/124) were usable photos (bears could be identified as either tagged or not tagged) (Figure 5). There were 84 photographs of tagged bears, and in fifty-two percent of these (44/84) individual bears could be identified (tag number was visible and legible); these forty-four photographs showed six different individuals. Two of these tagged bears were tagged after my study began, and thus were counted as "untagged" in the data analysis. One of the tagged bears that was photographed had lost its rear facing tag. Since the study was designed to capture the rear portion of the head region of the bear, the rear facing tag (in most cases) would be the one that would provide the positive identification of the bear. There were several pictures of this bear in which the entire rear head region was visible, and it was clear that the front-facing tag was there, and if the rear-facing tag were still present, most likely it would have been legible in all the photos. There were likely 14 more photographs of this bear in which the ear tag would have been visible and legible, in which case the percentage of photographs with individually identifiable bears would have increased to sixty-nine percent (58/84).

Figure 5. Bear L-02 at bait station. Bear is easily identified by visible and legible tag.

Table 1. Calculated estimates of bear population size, N, using various methods of analyzing multiple samples

Population Estimate	Method 1 2003	Method 2 2003	Method 3 2003	Method 4 2003	Method 5 2003
$N_{Petersen}$	66	91	83	52.5	59.5

$$N_{Petersen} = \frac{\text{total marked x total marked and unmarked caught in second capture}}{\text{Number of marked caught in second capture}}$$

Table 2. Data used to calculate population size (N) for the various methods.

Method	Total Marked	Marked & Unmarked in 2nd Capture	Number Marked in 2nd Capture
1 Every photo	35	119	63
2 Every discontinuous sequence	35	26	10
3 Photos separated by ≥24 hour period	35	19	8
4 Every trapping counted	35	30	20
5 Each trapped bear counted only once	35	17	10

In the first method, I counted every photograph in which any bear appeared as long as I could identify it as being tagged or untagged. I obtained a total of 119 photographs of bears that I could identify as being tagged or untagged; 63 of these were of tagged bears, and 56 were of untagged bears (Figure 6). This method produced the lowest calculated estimate (66) for the three re-sight methods (Table 1). Using the second method, I had a total of 26 qualifying sequences: 10 were of tagged bears, and 16 were of untagged bears (Figure 7). Method two produced the highest calculated estimate (91) of all methods used in this study (Table 1). Using the third method, I had 19 qualifying photographs: Eight were of tagged bears, and 11 were of untagged bears (Figure 8). Using the fourth method, there were 30 re-traps of marked and unmarked bears during my study. Twenty re-traps were tagged bears, and 10 were untagged bears. Using the fifth method, there were 17 marked and unmarked bears re-trapped during my study: 10 were tagged bears and 7 were untagged bears.

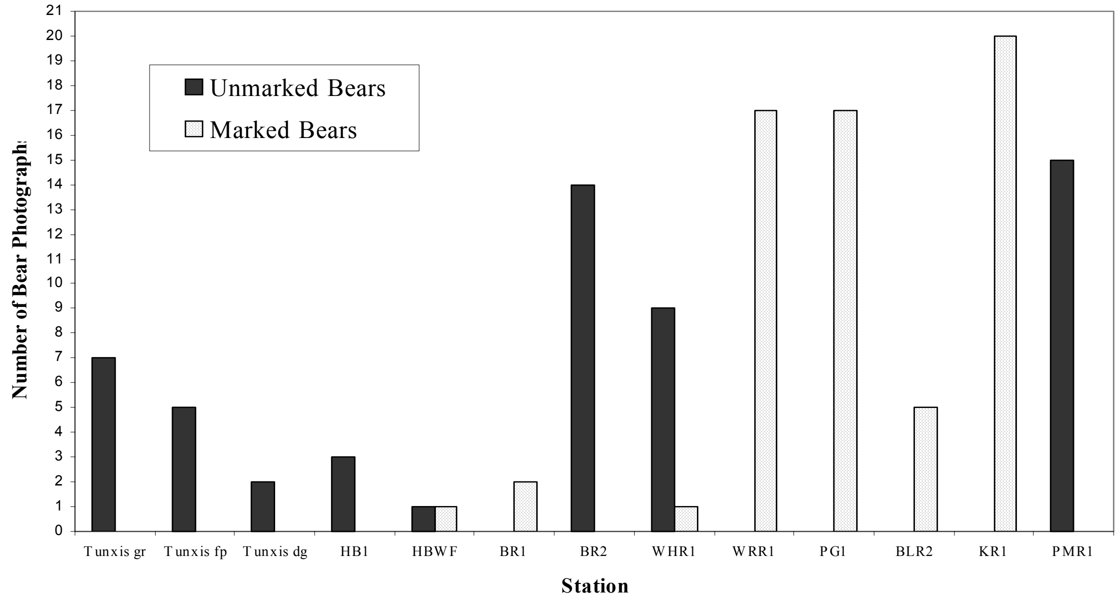

Figure 6. Total number of bear photographs per station.

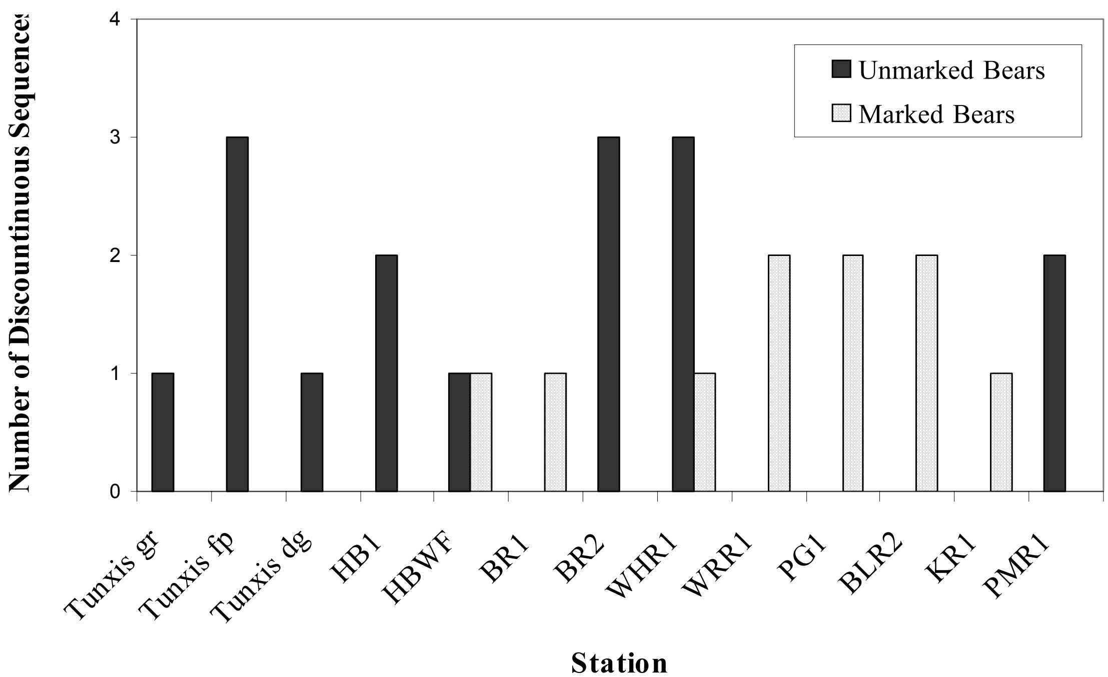

Figure 7. Number of discountinuous sequences of bear photographs per station.

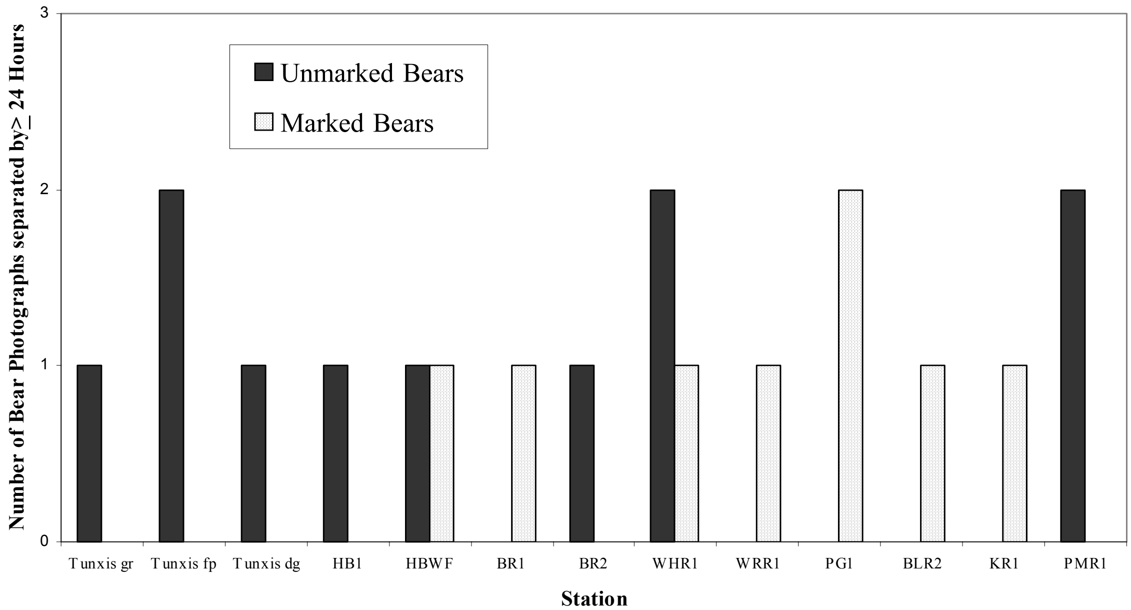

Figure 8. Number of bear photographs separated by $\geq$ 24 hour periods at each station.

I also looked at the behavior of individual bears. At the start of my study there were 35 marked bears. Seven more were marked during my study; among these, dates of marking of re-sighted or re-trapped bears are: 6-03: 27 June; 8-03: 3 July, and 9-03: 11 July. In the analyses that follow, I included all marked bears, but distinguish between those marked before and during my study.

Of six identifiable bears photographed, 1 was photographed only once; of the other 5, 1 was photographed twice, 1 seven times, 1 fourteen times, 1 twenty-one times, and 1 thirty-eight times (Figure 9).

There were 7 times in which the number of discontinuous sequences for individually identifiable bears at a particular camera station was equal to 1. One bear was photographed in 2 discontinuous sequences and one bear in 3 discontinuous sequences (Figure 10).

No individually identifiable bear was counted in more than one, 24-hour period at the same station (Figure 11). Although one bear appears to be counted twice and one three times, these sightings occurred at different stations.

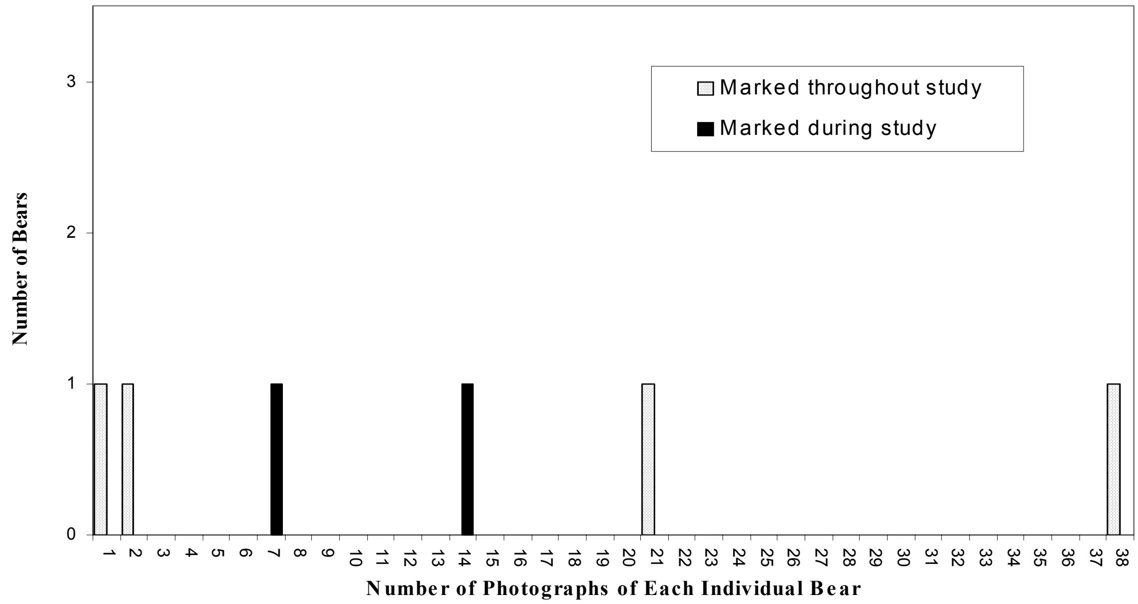

Figure 9. Number of photographs of individually identifiable bears (marked bears only).

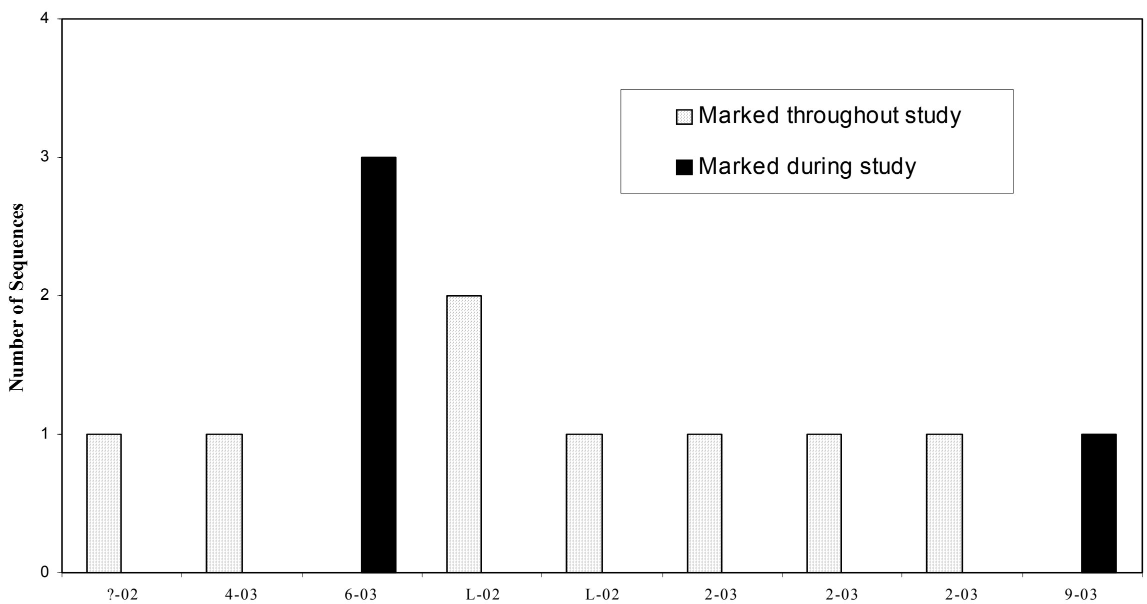

Figure 10. Number of discontinuous sequences for individually identifiable bears (marked bears only).

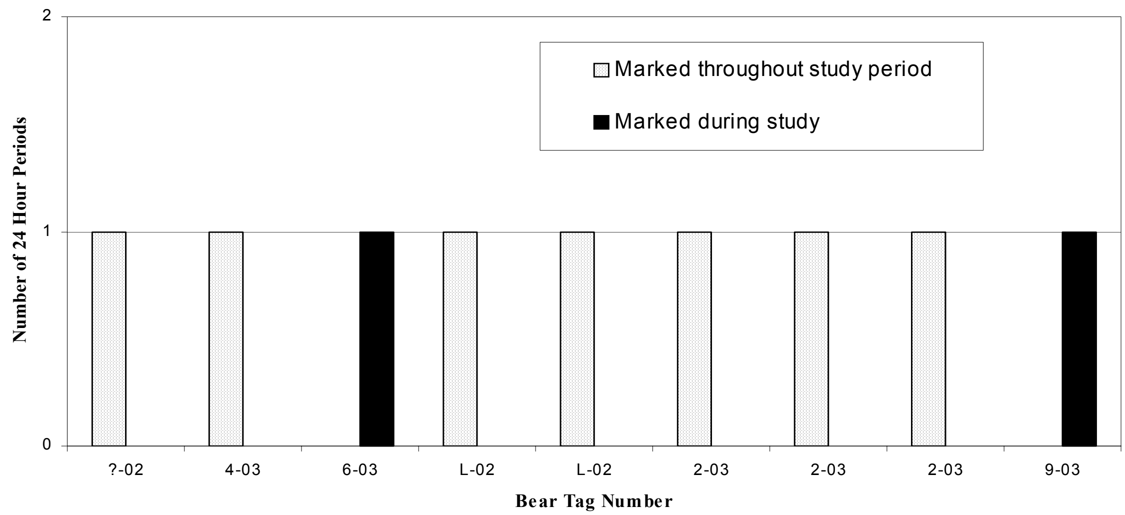

Figure 11. Number of bear photographs separated by greater than 24 hour periods for each individually identifiable bear (marked bears only).

Because tagged bears were individually identifiable, it was possible to determine the number of stations visited by each bear. Four bears only visited one camera station, one bear visited two different camera stations, and one bear visited three different camera stations s (Figures 12 and 14).

During the study period, 12 marked bears were re-trapped. Three bears were re-trapped once, seven bears twice, and two bears three times (Figures 13 and 14). Re-traps generally occurred at the same trap site at which a bear had originally been marked.

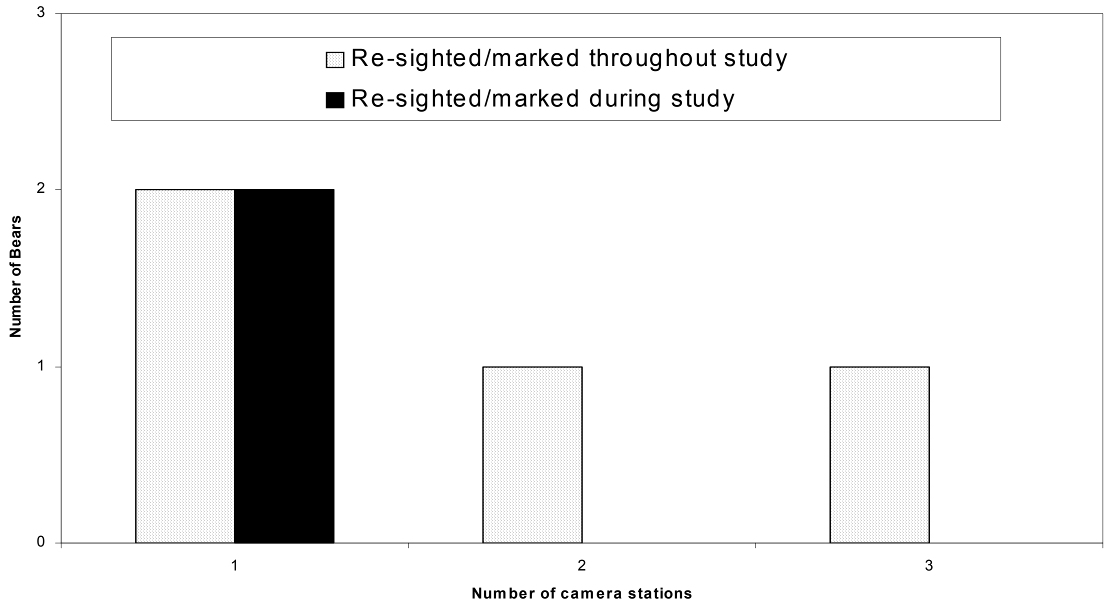

Figure 12. Number of camera stations visited by individually identifiable bears.

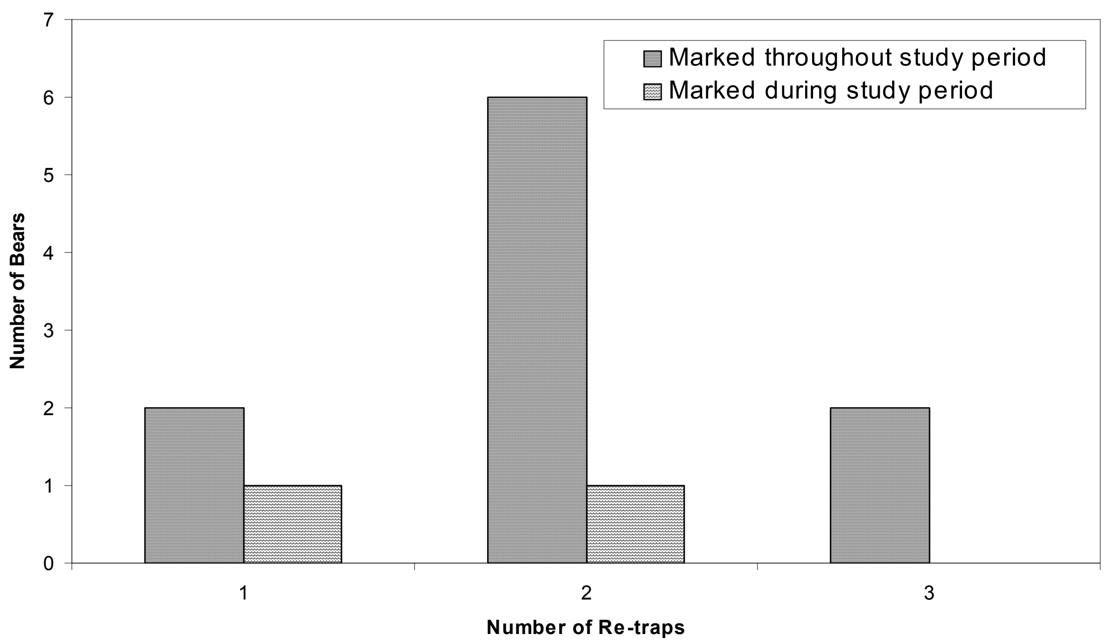

Figure 13. Number of re-traps of individually identifiable bears.

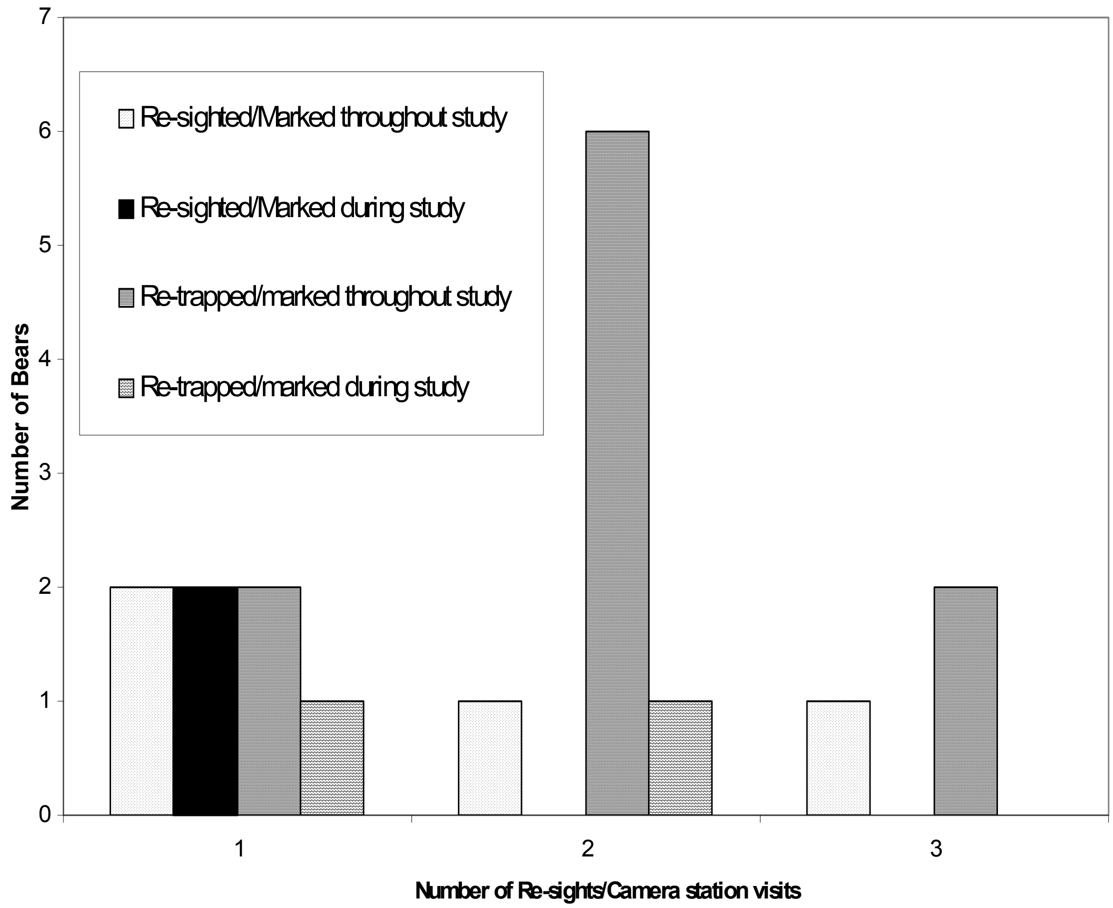

Figure 14. Number of re-captures and camera stations visited by individually identifiable bears.

At least 4 marked bears were both re-trapped and re-sighted during the study period. Bear ?-02 may also belong in this category, as it may be the same bear as 6-02 or 2-02 (photograph was taken too close to read the number before -02). One bear (L-02) was re-trapped and re-sighted twice, and bear 6-03 was re-trapped twice and re-sighted once. Bear 2-03 was re-trapped twice and re-sighted three times. Bear 4-03 was re-trapped three times, and re-sighted once. Two bears were not re-trapped, but were re-sighted once each (?-02 and 9-03). Eight bears were re-trapped but not re-sighted. Bear

6-02 was re-trapped 3 times, bears 2-01, 3-03, 2-02, and E-02 were each re-trapped twice; and bears 6-01, I-02, and 8-03 were each re-trapped once (Figure 15).

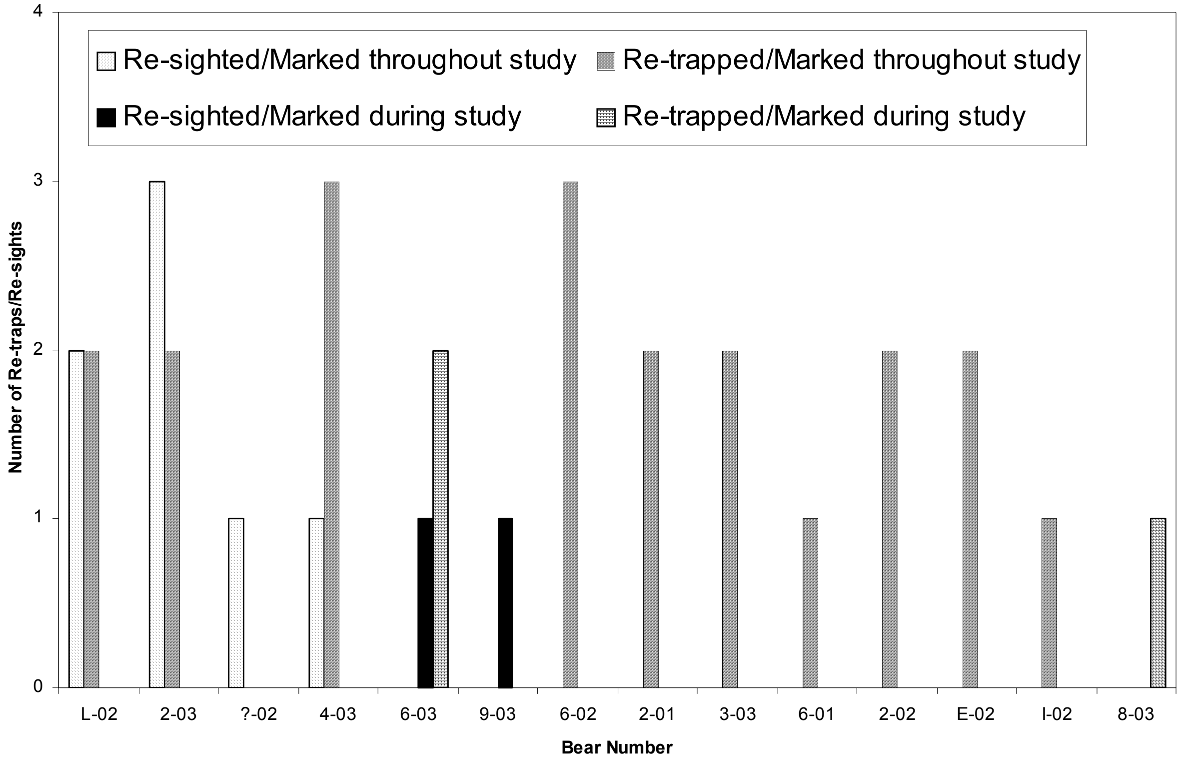

Figure 15. Number of photographs separated by greater than 24 hours and trap re-captures for each individually identifiable bear. (Note: Bear ?-02 could be the same as 2-02 or 6-02)

DISCUSSION

Method 1 produced a much lower population estimate (66) than both methods 2 and 3 (91 and 83, respectively). Method 1 differed from methods 2 and 3 in that it counted every single photograph in which bears were identifiable as tagged or not tagged. The cameras were designed and set up to take photographs continuously at 15-second intervals for the entire time the sensor detected motion or changes to the ambient temperature. Consequently, on several occasions I collected more than one bear photograph at a station. If one individual bear stayed longer or visited a station multiple times, I would have more pictures of it than another individual bear that stayed for a shorter period of time or only visited the site once. Theoretically, this would not affect the population estimate, as long as the marked and unmarked bears in the population were equally likely to be sampled multiple times.

Having a higher proportion of marked individuals to unmarked individuals in the second capture results in a lower population estimate. The population estimate that was calculated using method 1 clearly resulted from having a higher proportion of marked to unmarked bear photographs. When method 1 was used and every photograph was counted, the percentage of tagged bears was only slightly higher (53%, 63/119) than the percentage of untagged bears (47%, 56/119).

However, if one segment of the population (either tagged or untagged) were more likely to be sampled multiple times than the other segment, this situation would lead to bias in the estimate. This type of bias was most likely to occur in this experiment when every photograph was counted (as in method 1), because any inequality in the proportion of marked and unmarked bears photographed multiple times would be apparent (because method 1 produces counts proportional to the duration of the visit and the number of visits by the same individual bear at the same station).

Methods 2 and 3 attempt to correct for any bias associated with inequalities in the length of visit or number of visits, by only counting bears once per series of photographs (method 2) or once per 24-hour period (method 3), regardless of how many photographs were taken of each bear. When method 2 was used, the percentage of individual tagged bears was significantly lower (38% - 10/26) than untagged (62% - 16/26) bears photographed. Method 3 produced similar results to method 2 with the percentage of individual tagged bears at 42% (8/19) and untagged bears at 58% (11/19). These data indicate either that tagged bears stay longer than untagged bears at each visit, or untagged bears make more separate visits than do tagged bears, or both.

Methods 4 and 5 used trap capture data alone, from the state of Connecticut DEP, which allowed me to compare camera recapture estimates with trap recapture estimates. Method 4 was similar to method 3, because the state DEP does not generally capture more than one bear in a given trap in a 24-hour period.

Comparing methods 3 and 4 tells about trap-happiness vs. camera-station happiness. Method 4 produced a much lower population estimate than method 3, due to a large number of re-traps counted in method 4. This would indicate that bears were more likely to be trap-happy than camera happy. Unlike cameras, traps were left in the same place for long periods of time, and bears could learn and remember their locations to make multiple visits. Two of six bears photographed had multiple camera re-sights greater than 24 hours apart, while 9 of 12 re-trapped bears had multiple re-traps.

Method 5 was similar to methods 3 and 4. The difference between method 5 and the camera methods used in this study (and in general all camera resight methods) was that in the camera methods, there was no way to determine whether sightings of untagged bears were of the same bear or of different bears; therefore, all sightings of untagged bears had to be counted. For this reason, all sightings of tagged bears also had to be counted. For purposes of comparison, all sightings of all bears were also counted in method 4. However, in the state trapping efforts, every captured bear was tagged before release, so it was possible to avoid double counting both untagged and tagged bears. Method 5 produced an estimate that was closest to the estimate produced using method 1.

Comparing methods 4 and 5 tells about the effect of multiple sampling of the same bear for tagged vs. untagged bears. Multiple trappings of the same bear were counted in method 4, but not in method 5. The estimate for method 4 was lower than method 5 because a higher proportion of tagged than untagged bears were trapped multiple times. Therefore the ratio of tagged to non-tagged bears re-captured was higher using method 4, producing a smaller population estimate. This may indicate that tagged bears were or became trap happy, making them more likely to be caught multiple times.

Mark-resight studies have become an increasingly popular method (replacing the traditional mark-recapture study) for estimating population size (Cutler and Swann 1999). Sighting animals can be more efficient in terms of time and cost, and less intrusive than re-trapping (Martorello et al. 2001). However, the utility of a mark-resight study is dependent upon its ability to resight the target species in an efficient and effective manner.

The camera study took place over an 82-day period and produced 119 usable black bear photographs, with a total cost of approximately \$945: \$27 for hardware cloth, \$95 for batteries, \$45 for film, \$240 for film developing, \$490 for cameras, and \$48 for miscellaneous expenses. These costs do not include traveling expenses and there were no salary expenses incurred.

The percentage of usable bear photos to all bear photos taken was extremely high (96%). However, it must be noted that because there were multiple pictures taken of the same bear on many occasions, "usable" in this instance only means that bears could be identified as tagged or not tagged. Only one of the methods used in the study to calculate population size used all 119 black bear photos, in which I could determine whether bears were tagged. Two other methods used much smaller numbers, as these methods partially compensated for some of the pictures likely being of the same bear (this approach lowers the percentage of pictures actually used to calculate the population size to twenty-two percent (26/119) in the second method, and sixteen percent (19/119) in the third method). On the surface, these numbers appear to translate into a low success rate; however, they should not necessarily be interpreted that way.

It was my intent when designing this camera study, to be able to take more than one photograph at a station between checks. I believed that this would provide at least one picture in which I would definitively be able to identify whether the bear was tagged or not, and if it was, what the tag number was. There were only five bear pictures that could not be used. In one instance, the bear was too close to the camera when the photo was taken; in the others, the bears were around the back side of the tree, and their paws were visible, but their head regions were not. However, because the cameras took additional photographs shortly before and/or after each unusable photograph, I do not believe that I missed any visits by these bears.

In addition to time and cost considerations, using a different method of capture (in this case cameras) for the second sampling may help reduce bias (Buck and Thoits 1965, Minta and Mangel 1989, Seber 1970). At the beginning of this study, I believed that it was possible that bears might become trap 'shy' after the initial trapping. If re-trap data were used for population estimates, this 'trap-shyness' would lead to an overestimation of bears in the state, due to an overrepresentation of untagged bears being captured in the second sampling. However, after reviewing the data collected by the state of Connecticut DEP for the year 2003, it appears that if anything, some bears showed a propensity to visit the state traps and were captured multiple times. In fact, two bears were recaptured three times, and seven bears were recaptured twice, through the course of the study. This phenomenon would lead to an underestimation of animals, as a larger proportion of tagged bears are captured in the second round. These data suggest that perhaps some bears, instead of being 'trap shy', were perhaps 'trap happy'. It should be noted, however, that only eight of 35 bears that were tagged at the start of the study were recaptured more than once, and only 10 of these 35 were re-captured at all.

Using cameras as an alternative 'recapture' technique may have reduced some of the initial bias associated with trap happy bears. The steel culvert traps that the Department of Environmental Protection used as their capture method were baited with day old bagels and donuts. After the initial trapping (at which time the bears obtained food), the bears may have come to associate the culvert traps with food. It is possible that trapped (and therefore tagged) bears might return to the traps more frequently than bears that had not been trapped, (and therefore weren't aware of the food 'reward'). Although there was bait used at the camera stations, previously tagged bears had no association with the cameras (or the camera station locations), and would theoretically not be as apt to locate the camera stations with more frequency than untagged bears.

Once the camera stations were located by the animals, however, it is possible that we would experience the same type of bias (trap happy animals), possibly even more so because there were no negative consequences for the animals that obtained food from camera stations. However, in an attempt to mitigate this bias, bait was never refilled at a station once a bear had taken it, and camera stations were relocated after a bear was detected there. This methodology is quite different than the method of trapping used by the DEP. The steel culvert traps are very large, bulky, and difficult to handle and set up. In addition, they are very obvious, so DEP employees had to take special precautions to locate them in areas where the public would not come across them. It is for these reasons that the traps were not moved after a bear was captured, and in fact in many cases traps were moved only once or twice during the summer. Trap happy bears would therefore have no problem locating the traps and returning for more food. Camera stations, however, did not offer the same obvious indication of a food source (they were much smaller). Even if the bear were to make an association between the camera stations and bait, bait was not replaced, and stations were relocated at the latest four days after the detection of a bear at the site.

The camera study did reveal, however, that perhaps certain bears were more likely to be recaptured (either in traps or by other means) than other bears. Bear 2-03 was recaptured in the culvert traps two times throughout the course my study. This same bear was resighted with the cameras three times (at different stations) throughout the same study period. In addition, all but two of the bears that were resighted in the camera study were also recaptured in the culvert traps at least once during my study.

It is possible that these bears are less wary of people and/or are more curious than other bears and are therefore more likely to be initially captured and tagged, and more likely to be recaptured/resighted once they have been tagged. Bear 2-03 was one of the smaller bears captured to date. It is possible that this bear is young (the age of this bear is unknown), and thinks of these bait stations as a natural food source. Another possibility is that she is not a good forager and has come to rely on the bait as a source of food to survive. If she shares her home range with a larger, more dominant bear, she may not be able to compete for the natural food resources and must partially rely on alternative methods for obtaining food.

It is likely that in this experiment, there were slight departures from Petersen's assumptions. If there truly was a portion of the bear population that was less wary of people, and more curious, the potential exists that these bears had a greater probability of being caught in the first round (a violation of assumption (b)) (Seber 1970). In addition, some bears were recaptured multiple times (both in traps and on film), which may indicate that some bears were 'trap happy', (a violation of assumption (c)) (Seber 1970). The presence of 'trap happy' bears would lead to an underestimation of the true population.

However, the use of camera stations in place of traps, as the recapture method, was an attempt to mitigate the bias associated with 'trap happy' bears. The use of different methods of capture for the first and second sampling is one approach to accommodate assumption (c) (Minta and Mangel 1989). It is possible that the camera study reduced some bias associated with 'trap happy' bears (a lower number of recaptures would produce a larger population estimate). The estimates produced by methods 3 and 4 provide a good example of this scenario. There was a greater percentage of re-traps (method 4) than of re-sights (method 3), indicating that bears might be more 'trap-happy' than camera happy, which in turn produced a smaller population estimate using only the trapping data.

I believe that remote cameras were an effective and efficient method of recapture in this mark-recapture study. Cameras were less invasive and time consuming to use than trapping. Trapping required set up, maintenance of traps, personnel to check traps daily, and handling of animals; whereas cameras were easier and quicker to set up, didn't need to be checked daily, and didn't require animal handling.

The estimates produced from the photographs obtained in this research will provide the state of Connecticut with a baseline population of black bears within the study area. However, due to significant down time caused by camera malfunctions, it is recommended that additional research be conducted using more cameras, perhaps of a slightly better quality than the ones used in this study. More cameras would allow the researcher to cover a larger area. Additional cameras could also be set aside to be used as replacements for malfunctioning ones in the field. In addition, although the camera station set-ups were effective at producing a very high percentage of usable bear photographs (of all bear photographs), almost half the total number of photographs obtained were of non-target animals (the majority of these were raccoons). Additional studies should consider a bait station set-up that would limit access to the bait by non-target animals. For example, Mace et al. (1994) used a steel cable to suspend their bait between two trees. Although this may have been a feasible method to use, it would have been much more labor intensive and it more than likely would have required two people to get up into the trees to suspend the cable.

It is apparent from figure 14 that eight bears were re-trapped during this study period, but not re-sighted. Seven of the eight were re-trapped in my study area; the other bear that was re-trapped but not re-sighted was captured in Goshen CT (an area not included in this study).

Three of the eight bears were re-trapped in People's State Forest. All of my cameras in the trapping area around People's State Forest (except those that malfunctioned), did photograph bears. Once the camera station had a bear visit, the cameras were moved to a new location. It is likely that if I had stayed in People's State Forest longer, I would have re-sighted more tagged bears.

If this study were to be repeated, it might be reasonable to look more closely at the proportion of time and the number of stations located in any one area. Black bear home ranges appear to be big enough that tagged bears can move throughout the study area, in which case tagged bears could be re-sighted even if cameras were not placed in the immediate vicinity of a trap site. Even so, one might get a better overall representation of the black bear population if the cameras were placed systematically throughout the study area. The study area could be gridded into squares, and a camera could be placed at the center of each square at a randomly assigned time during the study, so the area in each square would be equally sampled. In addition, the researcher could track the number of days each camera was functioning at each station, to ensure that each site had an equal number of censusing days. Additional ‘back-up’ cameras could be helpful to replace non-functioning ones to eliminate time lapses between sampling.

By comparing methods 3 and 4 I was able to determine that there were more ‘trap-happy’ than ‘camera happy’ bears during this study. In re-traps, already marked bears made up 67% of the re-traps, whereas in re-sighting photographs, already marked bears only made up 42% of the re-sights. There’s also some evidence that the first bears to be trapped are generally more trappable. Traps captured bears that were tagged at the start of my study on average two times during the study period, and captured bears that were untagged at the start of my study on average only 1.5 times.

Although method 1 produced a population estimate closest to the estimate produced using a typical re-capture method (method 5), I would recommend using the population estimate produced using method 3 (83 bears). Method 3 was the most similar to methods 4 and 5, but resulted in a larger population estimate due to effectively reducing some of the bias associated with ‘trap-happy’ bears.

The cameras used in this study produced photographs that allowed me to effectively calculate the population size of black bears in my study area. I believe that the cameras were a viable, if not, better alternative to the traditional mark-recapture study, because the ability to move the cameras quickly and easily to a new station after a bear visit allowed me to sample a large number of locations at minimal cost and time, while reducing the bias associated with ‘trap-happy’ bears.

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