"Post capture activity level recovery times of Eurasian lynx *Lynx lynx* in Norway"

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ABSTRACT

Chemical immobilizations and handlings are commonly performed on numbers of wild animals each year and are the main methods for radio collaring, collecting biological samples and measurements, and obtaining information on the health, reproduction, and age structure of a population. However, these procedures are associated with risks such as behavior changes, injury, or death to our study subjects, and research on capture effects is lacking. The Eurasian lynx *Lynx lynx* is a commonly captured species for research purposes in Norway, and there are few studies investigating capture effects on this species. Using activity data obtained from accelerometers mounted on GPS collars, I determined the recovery times of 33 Eurasian lynx in Norway from capture and recapture events (n=45) and evaluated influences and differences on the recovery period in regards to capture methods, capture number, age, gender, pursuit time with helicopter captures, and whether or not surgery was performed. Overall, the current capture protocols and methods on Eurasian lynx do not have long lasting effects on the recoveries of the lynx from a capture event. Specifically, Eurasian lynx on average recover from a capture event within 2.0 days post capture. Age of the lynx was found to be the most influential factor on the recovery period. No statistical significance was found between capture methods, capture number, gender, age, or whether or not surgery was performed, although some differences in recovery times existed. Researchers should evaluate capture effects to not only ensure minimal human impact and continued existence of their study animals, but also to objectively refine capture methods as needed.

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1. Introduction

Chemical immobilization in combination with radio-telemetry are necessary tools that wildlife veterinarians and researchers utilize in order to gain a deeper understanding of the health, management, and conservation of many wild species in the world. Capturing and handling is the main method for radio collaring, collecting biological samples and measurements, and obtaining information on the health, reproduction, and age structure of a population (Thiemann et al., 2013). However, these procedures carry risks of death, injury, behavior changes, or other unknown side effects with them that cannot be eliminated even with healthy animals (Arnemo, Evans, & Fahlman, 2012; Thiemann et al., 2013). Scientific research aimed at evaluating the capture effects on wild animals provides a means for improvements to capture protocols and management to be objectively determined, higher standards of animal welfare to be upheld, a decrease in animal mortality to occur, and the impact of human involvement on wild species during capture to be minimized.

Publications evaluating short- and long-term effects of capture and handling have become increasingly common in the scientific literature in recent years (Neumann et al., 2011; Dennis & Shah, 2012; Thiemann et al., 2013; Rode et al., 2014). This increased desire to understand the effects of scientific research on wild animals is essential to ensure that we are not unknowingly negatively impacting the health and well being of our study population or receiving biased research data (Cattet et al., 2008; Jewell, 2013). Aside from obvious injuries incurred or mortalities, effects of immobilizing wild species may be difficult to detect or unknown, and it is commonly assumed that the study subjects behave in a similar manner as the other members of the species and comparable to pre-capture times (White & Garrot, 1990; Laurenson & Caro, 1994; Morellet et al., 2009). However, some investigations into the effects of capturing and handling of wild species suggest negative effects from capture events such as with the disruption of normal daily movements and activities (Dennis

& Shah, 2012; Morellett et al., 2009). Technological advances that increase our knowledge of the ecology of wild species can also be utilized for increasing our understanding of the degree of human impact imposed on wild species during chemical immobilization and handling.

A technological advancement that reveals more into the lives of wild animals' daily activities especially when we aren't able to directly observe them are accelerometers incorporated into Global Positioning System (GPS) collars. Direct observation of an animal's behavior is best for studying its activities, but isn't possible with the number of man-hours it would require, with animals having cryptic or nocturnal activities, or with those that travel great distances. Accelerometers measure the degree of accelerations in animals' motions (i.e. activity levels) (Gervasi, Brunberg, & Swenson 2006; Heurich et al., 2014). Knowing the variation in activity provides important information about behavioral ecology and objective data for management (Gervasi, Brunberg, & Swenson, 2006). They have been used before in wildlife studies such as with captive moose (*Alces* alces; Moen, Pastor, & Cohen, 1996), red deer (*Cervus elaphus*; Adrados, et al., 2003), and captive and wild bears (*Ursus arctos*; Gervasi, Brunberg, & Swenson, 2006) where the authors report a 75-94% correspondence between observed and sensor-measured activities. However, it should be noted that accelerometers provide information on the degree of activity (i.e. inactivity versus activity), but not specific behaviors in particular (Gervasi, Brunberg, & Swenson, 2006; Podolski et al., 2013).

Animal activity patterns and levels can vary due to a number of natural factors such as season (Heurich et al., 2014), prey activity and availability (Podolski et al., 2013), temperature (Podolski et al., 2013), reproductive status (Burdett et al., 2007), age (Heurich et al., 2014), gender (Burdett et al., 2007; Heurich et al., 2014), or with introduced factors such as anthropogenic activities (Wolf & Ale, 2009). With wildlife research, capture and handling also has the potential to disrupt an animal's normal daily activity pattern and levels (Rode et al., 2014). Morellet et al., 2009 found an overall decreased activity level in roe deer (*Capreolus capreolus*) the first 10 days after a capture event. Neumann et al. (2011) report of increased activity levels for 7 hours post-capture in moose.

The provided examples above demonstrate an approach to using activity levels to study the effects of capture: recovery times. Recovery should be defined on an individual species' daily activity patterns, modes of hunting, or different life history stages of the animals being studied. No matter the definition though, dissimilarities in the recovery of activity levels can be a result of species differences, capture methods, or immobilizing agents administered, therefore, it is imperative that researchers are aware of the potential implications chemical immobilization and handling can have on their study species especially for those that are endangered.

Chemical immobilizations and handlings are commonly performed on numbers of wild animals each year, and even with the increase in scientific publications about capture effects, research is still lacking for some of the commonly captured species. The Eurasian lynx (*Lynx lynx*) in Norway is one of those species. As a controversial carnivore in Norway, lynx have been immobilized and radio-collared by the Scandinavian Lynx Project (SCANDLYNX) in order to provide data on the locations and activities since 1994 (Linnell et al., 2005). In recent years, some lynx have had intra-abdominal surgeries for the placement of transmitters, and to my knowledge only a few studies investigating effects of capture have been conducted but primarily focused on capture mortality (Arnemo et al., 1999; Arnemo et al., 2006). Most recapture research to date has focused on body condition, aspects of reproduction, or movement rates (Ramsay & Stirling, 1986; Cattet et al., 2008). Moa et al. (2001) evaluated Eurasian lynx space use after a capture event and concluded that it took lynx a longer time to return to the capture area compared to other areas. Here, I investigated capture effects on Eurasian lynx recovery times in Norway. Specifically, I determined:

- Recovery times from capture and recapture events based on activity levels (from accelerometers incorporated into GPS collars).
- Most significant factors influencing the recovery periods (modeling). Variables included gender, age, capture method, number of times captured, and pursuit time.

My overall objectives were to evaluate recovery (based on activity data) and note any variation between demographic groups (e.g. different sex and ages of lynx). Additionally, I sought to understand if certain parameters significantly influenced the recovery period and how they affected recovery.

2. Methods and Materials

2.1 Study Area and Animals

In the winters between 2008 and 2013, 45 capture events involving 33 free-ranging Eurasian lynx occurred. The lynx were captured and marked for research purposes in southern and northern areas of Norway under permits from the Norwegian Experimental Animal Ethics Committee and the Norwegian Environment Agency. The northern part of the study area is dominated by alpine tundra with a coastal alpine climate (Mattisson, Odden, Linnell, 2014). There are also large areas of mountain birch forest (*Betula pubescens*) interspersed with small patches of pine forest (*Pinus sylvestris*) along with coastal areas in some valleys (Mattisson, Odden, Linnell, 2014). Reindeer and domestic sheep comprise the main items of the lynx diet in the north, but they occasionally hunt small game (Mattisson et al., 2011). Managed forests comprised of Norwegian spruce (*Picea abies*), Scots pine (*pinus sylvestris*), and the deciduous birch (*Betula* spp.) mixed with modified agricultural land dominate the landscape in the southern portion of the study area. Roe deer and domestic sheep (summer) are the main prey items for lynx in the south, but they also consume mountain hares (*Lepus timidus*), black grouse (*Tetrao tetrix*), capercaillie (*Tetrao urugallus*), and red foxes (*Vulpes vulpes*) (Odden et al., 2006; Nilsen et al., 2009). Lynx in the study areas are controlled by hunted harvest (Gervasi et al., 2014).

The capture season for lynx typically occurs at the start of or during their breeding season (January- March). During this time period, the male lynx typically have increased activity levels and expanded their home range sizes due to breeding activities while the females have little changes in their activity levels (Sunde et al., 2000; Burdett et al., 2007). Outside of the capture season, reproductive female lynx can have reduced activities (Burdett et al., 2007) initially after having kittens around May-June, but their activity levels increase quickly while hunting to fulfill caloric needs for lactation and for the kittens (SCANDLYNX (n.d.); Heurich et al., 2014). In general, lynx are most active in the autumn and summer and least active in the winter and spring (Heurich et al., 2014; Podolski et al., 2013). Additionally, Heurich et al. (2014) determined that although the durations of daily active phases for lynx varied with the changing seasonal photoperiod, lynx were typically most active at twilight and during the night and least active during midday.

2.2 Capture Methods

Standard capture and surgical protocols for Eurasian lynx have been previously described elsewhere (Arnemo, Evans, & Fahlman, 2012). Lynx in this study were either immobilized from a helicopter (n=33) or captured in box traps (n=7) or snares (n=5) then immobilized.

Briefly summarizing from the helicopter, each lynx was darted initially with a mixture of 4 mg medetomidine (Zalopine®) and 100 mg ketamine (Narketan 10®) via a remote drug delivery system (Dan-Inject®). For those lynx captured in a snare, capture personnel typically arrived at the scene and started the immobilization within 10-15 minutes after the lynx was caught. For box trap captures, lynx were typically immobilized within 8 hours (average 5 hours) after being caught in the trap. Calm lynx caught in box traps or snares were immobilized with a reduced drug mixture of 2 mg medetomidine and 50 mg ketamine. All drugs were delivered from a 1.5 ml dart syringe with a 1.5 X 25 mm barbed needle (Dan-Inject®).

After immobilization, lynx were placed in lateral recumbency and an initial temperature, pulse rate, and respiratory rate were obtained. These parameters in addition with capillary refill time and the blink reflex were monitored frequently throughout the capture to assess the animal under anesthesia and the depth of anesthesia. Then, the lynx were equipped with GPS collars with accelerometers and biological samples were obtained according to the aim of the research projects at hand. Also, if surgery was performed for the placement of transmitter intra-abdominally, the lynx received 0.2 mg/kg meloxicam (Metacam®) prior to the surgery initiation.

Upon completion of all the capture procedures, each immobilized lynx received 5 mg atipamezole (Antisedan®) per milligram of medetomidine previously administered intramuscularly. Typically, immobilized lynx were left at the site of capture to recover undisturbed. The immobilization team typically left the site after initial recovery of each lynx (i.e. after the lynx was mobile again).

2.3 Activity Analyses: Activity Levels and Recovery Times

I defined activity as the movement of the lynxes' bodies as it was all inclusive of possible motions and activities (e.g. patrolling home ranges, hunting, feeding, etc.) The accelerometers in the GPS collars measured activity levels on dual axes, X and Y. The X-axis measured the acceleration of forward and backward motion, while the Y-axis measured sideways and rotary motions (Krop-Benesch et al., 2011). Measurements were taken every 8^{th} second and averaged for five-minute intervals that were then recorded (Krop-Benesch et al., 2011). The activity level scale ranged from 0 (no activity) to 255 (high activity) (Krop-Benesch et al., 2011). Due to the high correlation between these axes, I only used one, X, for calculations as was done in previous activity studies (Podolski et al., 2013; Heurich et al., 2014).

The raw data activity files (ADF files) were imported into my computer, cleaned, and exported to Excel with the help of two special programs, "Activity File 1.2.3" and "GPS Collar Plus X", both available online by Vectronic Aerospace (http://www.vectronic-aerospace.com/wildlife.php?p=wildlife_downloads). The activity periods, the time span between the start and stop time of each activity file, were determined by the individual capture protocols. Start time was the time the reversal agent was administered to each lynx, and the stop time was either the time of the next capture event, when the collar malfunctioned or battery was depleted, or when the lynx died (e.g. hunted/natural causes).

Each capture period, the time span between subsequent captures, and activity period within each capture period, the time when activity data was recorded on each lynx, were unique time periods for each lynx (e.g. different nutritional status, previous capture history, different environmental conditions, etc.). Therefore, calculations for each activity/capture period were performed separately. Average activity levels for each activity period for each lynx were calculated based on daily averages for the total amount of data that was available for each lynx within each capture period. Since objective data on the activity levels of wild lynx never captured were not available, these calculated activity levels were considered the overall, general "norms" for each lynx. Heurich et al. (2014) noted increased activity levels in male lynx versus females, in sub-adult lynx versus adult lynx, and seasonal and latitude differences in activity levels. Therefore, by determining the normal average activity levels for each study lynx and period, I was able to account for general differences in activity among lynx and individualize recovery periods. Recovery in this study was defined as the time when the post capture activity level of each lynx met or exceeded the lower 95% confidence limit of the average activity level for each capture period (confidence interval was estimated based on variation between daily means of activity). Post capture activity levels were averaged to 12-hour periods starting at the time of given antidote in order to account for the daily activity pattern of the lynx (Heurich et al., 2014).

Additionally, due to small sample size, the data for the third through fifth capture periods were combined.

2.4 Statistical Modeling

I used general linear mixed models (GLMM) to determine what factors significantly affected the recovery times of lynx after a capture event. Hence, the determined recovery variable was used as the response variable in all models. Due to the nature of the available data set, two sets of models were performed: one on all captures combined (n= 45) and the other only with helicopter captures (n= 33). Separating the captures was done because recaptures were only done via helicopter (exception of one snare recapture), surgeries were only performed when the helicopter was used for captures, and only adult lynx were recaptured. Lynx ID was used as a random intercept in all models in both sets to account for multiple captures of the same individual.

Explanatory variables chosen for the models evaluating all captures were ones that could potentially influence the recovery period and were of explicit interest to the recovery of a capture event: a parameter that capture and anesthesia can affect and potentially cause long-term health consequences if not managed properly during capture (i.e. temperature), how the animal was captured (i.e. the capture method), and biological data obtained from each lynx captured (i.e. gender and age) (Table 1). Hypothermia (body temperature > 37°C) is a common complication of anesthesia as normal thermoregulation becomes compromised (Armstrong et al., 2005). It has the potential to negatively effect hepatic, cardiac, and renal function, coagulation, immunity, and wound healing (Armstrong et al., 2005). Additionally, mild hypothermia has been shown to prolong recovery times (Armstrong et al., 2005).

The explanatory variables evaluated for the recoveries of the helicopter captures were unique to only those captures and could potentially influence recovery time: capture number, pursuit time, and surgery (Table 1). Pursuit time, as indicated on the capture protocol, began at the time capture personnel in the helicopter observes the animal and ended once the animal was lying down after being darted. It included chase, darting, and anesthetic induction times. Pursuit time was only available for 26 capture events, reducing the dataset in the models. Thiemann et al. (2013) theorized that polar bears that ran more during pursuit time had higher muscular oxygen demands that could have resulted in mild hypoxemia and longer recovery times.

Table 1: Summary of the explanatory variables used in the GLMMs to determine the significant factors influencing recovery time in lynx.

Variable name	*Type of variable*	*Definition*
Capture method	Categorical	Helicopter, Box trap, or Snare
Gender	Binomial	Male or female
Age	Binomial	Sub-adult (0.5 -2 years) or Adult (2+ years)
Temperature	Continuous	Numerical value (°C); Last temperature obtained during capture event before lynx were reversed
Capture number	Continuous	1-3+[a]; Number of times lynx were captured during study period
Pursuit time	Continuous	Time from lynx observation until lying down after being darted
Surgery	Binomial	Yes/No; Whether or not a transmitter was surgically placed in the abdomen

[a]: Capture periods 3-5 were pooled to account for low sample size.

For both sets of models, candidate models were created from various combinations of the chosen variables. All models were run in R, (version 3.1.1), as GLMERs with a Poisson distribution using the package 'lme4' (package: lme4_1.1-7). Poisson distribution was used as the recovery data was highly skewed towards lower values thus creating overdispersion. To be able to fit a Poisson distribution, recovery times were adjusted to integers by giving each 12-hour mean a value of 1 (i.e. 0.5 days =1, 1 day = 2, 1.5 days = 3, etc.). Model selection was based on Akaike's Information Criterion (AIC_c). Finally, variables were interpreted based on the individual estimates provided. Section 3.1 “Capture Data Overview” provides a summary of the capture data used in the analyses. All calculations for data overview and recovery analyses were performed in Microsoft® Excel® (Microsoft® Excel® for Mac 2011).

3. Results

3.1 Capture Data Overview

Forty-five capture events occurred between 2008-2013 where Eurasian lynx in Norway were fitted with GPS collars with activity sensors: 27 captures were the initial captures for the lynx while 18 recaptures occurred during the study period. A summary of details of each capture period is presented in Table 2. The duration of the activity periods was on average 335 days (SE = ±9.5; range: 137-474 days; n=45).

Table 2: Summary of details for individual capture periods for Eurasian lynx in Norway 2008-2013 (±SE; range).

Capture Period	***1st***	***2nd***	***3rd-5th*** [a]
Sample Size (M/F)	27 (12/15)	10 (3/7)	8 (4/4)
Age of lynx (# sub-adult/adult)	10/17	0/10	0/8
Average activity period (days)	329 (±12.89; 137-435)	372 (±15.74; 308-474)	297 (±20.75; 236-394)
# Surgeries	4	1	2
Capture methods: # lynx	Helicopter: 16 Box trap: 7 Snare: 4	Helicopter: 9 Snare: 1	Helicopter: 8
Average time between captures (days)	416 (±51.05; 361-722)	438 (±57.31; 367-751)	417 (±39.53; 366-751)

[a]: Capture periods 3-5 were pooled to account for low sample size.

3.2 Recovery Times

Overall, the time for Eurasian lynx in Norway to recover from a capture event was 2.0 days (SE: ±0.34 range: 0.5-12.5 days; n= 45). Table 3 provides a summary of the recovery times between capture events, capture methods, and between demographic groups. There was no statistical significance between the differences in recovery times between capture number/event (ANOVA; $F_{1,42}$= 1.16, p = 0.32), capture methods ($F_{2,42}$= 0.60, p = 0.55), gender ($F_{1,42}$= 2.31, p = 0.15), age ($F_{1,42}$=3.72, p = 0.06), or whether or not surgery was performed ($F_{1,42}$=0.03, p = 0.87). Over the course of five capture periods, 60% of the recovery periods occurred within 0.5-1 day post capture. See Figure 1 for a summary of capture recovery ranges.

Table 3: Summary of recovery times for Eurasian lynx captured in Norway between 2008-2013 (±SE; range; sample size)

	Recovery
Capture Event	
1st	1.9 days (±0.45; 0.5-12.5 days; n=27)
[without outlier]	[1.4 days (±0.22; 0.5-4 days; n=26)]
2nd	3.1 days (±0.97; 0.5-8.5 days; n=10)
[without outlier]	[1.2 days (±0.29; 0.5-1.5 days; n=7)]
3rd+	1.7 days (±0.51; 0.5-4 days; n=8)
Capture Method	
Helicopter	2.2 days (±0.45; 0.5-12.5 days; n=33)
[without outlier]	[1.8 days (±0.30; 0.5-7.5 days; n=32)]
Box Trap	1.2 days (±0.34; 0.5-2.5 days; n=7)
Snare	2.6 days (±1.22; 0.5-7 days; n=5)
Gender	
Male	2 days (±0.62; 0.5-12.5 days; n=19)
[without outlier]	[1.4 days (±0.20; 0.5-3.5 days; n=18)]
Female	2.1 days (±0.43; 0.5-8.5 days; n=26)
Age	
Sub-adult	2 days (±1.17; 0.5-12.5 days; n=10)
[without outlier]	[0.9 days (±0.14; 0.5-1.5 days; n=9)]
Adult	2.1 days (±0.33; 0.5-8.5; n=35)
Surgical Procedure	
Yes	1.2 days (±0.29; 0.5-2.5 days; n=7)
No	2.1 days (±0.41; 0.5-12.5 days; n=38)
[without outlier]	[1.9 days (±0.29; 0.5-7.5 days; n=37)]

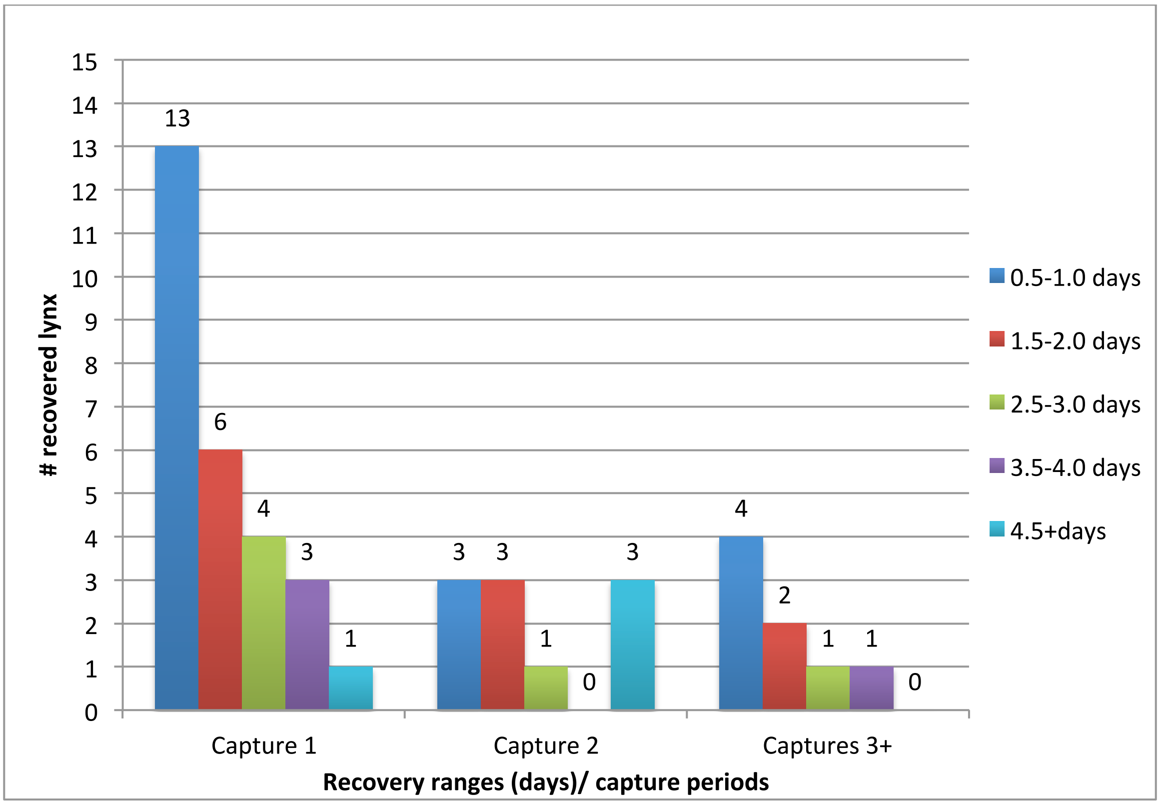

Figure 1: Ranges of recovery times of Eurasian lynx captured in Norway between 2008-2013. Superscripts above each bar indicate sample size.

The longest recovery times (>4 days, n=4, 9%) occurred after the first and second capture events. After the first capture event, one sub-adult male captured by a helicopter (no surgery) took 12.5 days to recover. Three adult female lynx captured a second time took 6.5 days (helicopter), seven days (snare capture), and 8.5 days (helicopter) to recover.

3.3 Recovery Modeling

All Captures

Age was found to be the most significant factor affecting lynx recovery (Table 4). A negative estimate (β= -0.7209, SE= ±0.32, p=0.02) for the sub-adult lynx age category indicated that the younger lynx had shorter recover times. The remainder of the models tested possessed ΔAICs that were greater than two, meaning that there was no significant influence of gender, temperature, or capture method on recovery times.

Table 4: AIC results from model selection concerning recovery times after Eurasian lynx captures (n=44) in Norway 2008-2013.

Model	**AIC_c**	**ΔAIC_c**	**AIC_c weight**
Age	207.2737	0	0.3587
Temperature + Age	209.3283	2.0546	0.1284
Gender + Age	209.3537	2.0800	0.1268
Capture method + Age	210.1469	2.8732	0.0853
Null model	210.2975	3.0238	0.0791

The longest recovery outlier, determined by a boxplot graph (recovery = 12.5 days), was removed to improve model fit (n= 44). With keeping the outlier present, age was still considered to be the most significant variable affecting recovery, but I received results that were not consistent with my calculations of recovery times: that sub-adult lynx had longer recovery times compared to adults. Removing more outliers did not improve model fit further.

Helicopter Captures

The null model was the best model testing the significance of the pursuit time, surgery, and capture number on recovery meaning that none of the including variables affected recovery times. The age variable was also included as an explanatory variable with these models since its significance was demonstrated for the models for 'All Captures'. However, again, none of the variables I tested proved to have a significant effect on the recovery of lynx captured via helicopter. The AIC_c results for the null model and those models with ΔAICs within two of the best model are presented in Table 5.

Again, the longest recovery outlier (recovery = 12.5 days) was removed in order to improve model fit (n= 25). With it present, the results were heavily influenced, and I received results that were not biologically realistic: that surgery reduced recovery time. The outlier was a sub-adult lynx who was captured by helicopter but did not have surgery. Removing more outliers did not further improve model fit.

Table 5: AIC results from model selection concerning Eurasian lynx helicopter captures (n=25) in Norway 2008-2013.

Model	**AIC_c**	**ΔAIC_c**
Null	117.1145	0
Pursuit time	117.1277	0.0132
Surgery + Pursuit time	117.2069	0.0924
Surgery	117.9734	0.8589

4. Discussion

In summary, Eurasian lynx on average recover from a capture event by 2.0 days post capture. Age is the most important factor affecting the recovery of lynx after a capture event. Gender, capture method, capture number, pursuit time with helicopter captures, and whether or not surgery was performed did not influence recovery times. Four (9%) prolonged recoveries (> 4 days) occurred throughout the entire study period.

4.1 Recovery

Species differences: defining recovery and recovery rates

Previously published articles concerning capture effects on wildlife determined post-capture recovery with movement rates (Cattet et al., 2008; Thiemann et al., 2013), ranging behavior and activity (Morellet et al., 2009), or with both post-capture movement rates and activity levels (Rode et al., 2014). Although all were evaluating recovery rates from a capture event, they have different definitions of recovery. Cattet et al. (2008) defined recovery as when the mean daily movement rate reached the mean daily movement rates averaged over 70 days post capture. A study conducted by Thiemann et al. (2013) calculated 12- hour intervals movement rates post capture and compared them to a maximum 60 day post capture activity level to determine recovery times for polar bears. Rode et al. (2014) combined both definitions in their recovery study. Comparing these study designs with bears and recovery definitions to my current study, differences among them exist due to different life history traits. Theimann et al. (2013) state that movement rates after 60 days post capture are not indicative of pre-capture rates as after this time period, the polar bears move into different habitats and aspects of their annual life-history cycle. It has been previously noted that lynx have difference seasonal activity levels and that there are differences in activity levels between genders and residing latitude levels (Heurich et al., 2014). Lynx were typically captured in winter so in order to account for activity variations, I determined the overall "normal" activity level of each lynx during the entire capture period, being almost a full year (335 days $\pm$ 9.5 SE). Additionally, lynx are home range holders and don't seasonally change their locations, therefore, they typically reside in similar habitat (Herfindal et al., 2005).

Studies have demonstrated differences in recovery rates of wildlife from capture events. My current study determined that activity levels of Eurasian lynx recover from capture within 2.0 days on average. Activity levels for polar bears were most reduced during the first 2.6-5.3 days after capture, and full recovery of activity levels doesn't occur until 3.6 days post-capture (Rode et al., 2014). European roe deer (*Capreolus capreolus*) have overall decreased activity levels during the first 10 days after being captured (Morellet et al., 2009). Aside from differences in definitions of recovery, it should be noted that major differences between capture methods occurred among these species. The roe deer in the Morellet et al. (2009) study were captured in nets and handled while the polar bears in the Rode et al. (2014) study were immobilized only with irreversible drugs. In lieu of these differences, it makes the comparison of recovery times between species difficult if not impossible, but not all wildlife can be captured in a similar method so as to be able to compare species to each other. What is more important is to evaluate capture methods within each species in light of the specific life history traits, ecology, and environment that a particular species experiences.

Evaluating the recovery times of Eurasian lynx in Norway

Although there were differences in recovery times among capture methods, they were not statistically significant. There was a tendency for snare captures to have longer recoveries on average compared to helicopter or box trap captures. If an animal experiences a severe perturbation, an emergency life history stage is triggered (Wingfield, 2005). This life history stage directs the animals away from normal daily life and whichever life history stage it is currently undergoing into survival mode until the stress and perturbation pass (Wingfield, 2005). This rapid life history switch comes at an energetic cost to the animal from which it must recover from in addition to the capture event itself. Even though capture personnel are at the scene within 15 minutes after the lynx is captured by the snare, the lynx have the tendency to have longer recoveries with this method. Further investigations with blood serum values evaluating the amount of muscle damage (e.g. aspartate aminotransferase (AST), creatine kinase (CK), or myoglobin) occurring with snare captures could be performed to help researchers better understand the longer recovery times associated with these captures (Cattet et al., 2008).

No statistically significant differences were determined between genders, but age was determined to be the most influential factor on the recovery period for lynx. As a sub-adult lynx, they are in active pursuit of finding a territory to defend and prey to hunt. Therefore, the benefits of holding a territory for Eurasian lynx must outweigh the costs to not having a home range to defend as it shortens recovery time. Another possibility for age being the most influential on recovery time is due to higher metabolisms in the younger lynx.

No statistically significant differences were found between capture periods. Comparing between the capture periods is difficult as each capture period is a unique time period in the study, and different capture methods were utilized (e.g. all three capture methods were performed during for the first captures, only one snare recapture occurred, and the rest of the recaptures were via helicopter). Many factors could change between capture periods that could affect the recovery period: local weather and habitat conditions (Bier & McCullough, 1990; Villafuerte et al., 1993; Beltrán & Delibes, 1994), prey availability (Podolski et al., 2013), the presence of kittens with female lynx (Heurich et al., 2014), body conditions (Dechen Quinn, et al., 2014), whether or not the lynx was a territory holder (Moa et al., 2001), and the size of the home range (Moa et al., 2001). Additionally, the time of the capture could potentially influence the recovery rate of a Eurasian lynx. Heurich et al., (2014) discovered that Eurasian lynx are most active around twilight and night and least active around noon. Therefore, if the lynx were captured during a time when they are normally not very active, it is possible that their daily activity pattern could have a strong influence on their recovery time. This is the reason for doing a 12-hour average of activity post capture. The same holds true for if they were captured during a time when they are normally most active. This study was not an all-inclusive study investigating all factors that could alter recovery times and with many unaccounted for variables, further research is warranted to delve further into the recovery period.

A few prolonged recoveries were determined during the study period, and the longest recovery (12.5 days) was removed during modeling to improve the fit of the models. A possibility for these longer than average recoveries is muscle injury at the dart injection site (Cattet et al., 2006). Although difficult to measure, individual plasticity/variation (Thiemann et al., 2013) could play a role in the recovery periods. Additionally, the immobilizing agents have the potential to influence the recovery period. Drugs were administered on standard weight estimations, as lynx cannot be weighed before they are immobilized. Each lynx metabolizes the immobilizing agents at different rates and have different degrees of kidney functions to filter the drug metabolites (Riviere & Papich, 2009). Additionally, some lynx receive supplemental doses during the capture, but was not included as a variable in the models as the lack of complete capture forms would have further reduced the data set for performing the models. Nevertheless, one of the drugs used to immobilize lynx, medetomidine, was reversible. The other drug used, ketamine, has been found in domestic cats to have a elimination half-life of 78.7 minutes (Riviere & Papich, 2009), therefore depending on the whole capture time and if and when a supplemental dose was administered during the capture event, this drug could influence the recovery period. With this current study, the average capture time was 96 minutes (SE: ±8.09; range: 31-146 minutes), and none of the prolonged recoveries were associated with the shorter capture times. Additionally, Thiemann et al. (2013) included drug dose as a variable in their recovery study on polar bears and found no correlation between recovery rate and the drug dose received.

4.3 Conclusion

In general, the capture procedures performed on Eurasian lynx in Norway do not have long lasting effects on recoveries. More objective studies should be pursued with activity levels on Eurasian lynx in Norway so that the recovery definition and determination could be refined and better estimated. Additionally, further research correlating post-capture activity data with GPS movements in conjunction with weight could be performed to improve the knowledge of Eurasian lynx and their recovery period. It is important that research involving post-capture effects continue so that we as researchers ensure refinement of our research methods minimal impact on our study subjects to allow for continued persistence of animal species.

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