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# How Does Stress Affect Reintroduction and Translocation Attempts?

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# ABSTRACT

Reintroductions and translocations are important tools for increasing wild populations of animals under threat. The most important aspect of these attempts are survival and successful reproduction of the released animals. Stress is known to impact animal survival and reproduction, however until recently the impacts of stress on a reintroduction or translocation attempt were not well studied. While stress can be beneficial in certain circumstances, the negative effects of stress may have strong impacts on the success or failure of these attempts to establish new breeding populations. The trapping of wild animals, handling process, and type of release used in a study have been found to cause significant stress in wildlife, sometimes resulting in failure of the reintroduction or translocation. Variables post-release, such as predation, disease, and anthropogenic disturbance, have also been found to cause stress in wildlife. In this thesis, I develop a "stress-focused" framework for making decisions about reintroduction or translocation techniques. I outline physiological and behavioral markers of stress, conduct a targeted review of the literature on how stress affects success of translocation or reintroduction attempts, and make recommendations for limiting negative stress in future reintroductions and translocations.

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# Chapter 1
# Introduction

Reintroduction and translocation are common tactics used to promote the establishment of a new population of a species. Reintroduce is defined as “to return (a species of animal or plant) back to a locality where it was formerly native, with the intention of re-establishing it in the wild” (“Reintroduce, v.,” 2021). Animals being reintroduced may be from a wild source population or captivity. Translocation is defined as “the deliberate movement of free-living animals from one part of their range to another” (Bosson et al., 2013). A reintroduction or translocation is considered successful if the animals form an established population in the new habitat with limited mortality or health issues, as well as limited dispersal (Dickens et al., 2010, as cited in Bosson et al., 2013). Successful reproduction after reintroduction or translocation is also important to ensure the population will be self-sustaining. There are many causes for species decline, for example, negative interactions with invasive species, habitat loss, and anthropogenic disturbance. It is accepted that a successful reintroduction or translocation attempt requires managing or eliminating the key threats which led to the original population decline (Berris et al., 2020).

A major consideration for designing reintroductions or translocations is the method of initial release into the wild. In a “hard” release, the animal is directly released upon arrival, which minimizes the handling and transportation time (Jenni et al., 2015). In a “soft” release, the animal is instead temporarily confined at the release site with the goal that the animals will acclimate to their new environment prior to release which will increase survival and limit dispersal. Animals can be held for a few hours up to several months, depending on the method of the study, and the basic needs of the animals are available (Resende et al., 2021). Based on my survey of the literature (see below), there clearly is an abundance of variability in how hard and soft releases are conducted. For example, the method for confinement may differ between studies, from a small cage-like structure to a fenced-in pen spanning several acres. Animals may be held as individuals or in a group setting. Both hard and soft release techniques may have varying captivity periods prior to transport to the release site, from hours to months. While the type of release is clearly an important variable that differs between reintroduction and translocation attempts, several other contributing factors will be explored in this thesis.

I suggest that stress is a common thread tying together the various factors affecting reintroduction and translocation success and that a consideration of the effects of stress can positively guide the particular choice of methods used (Figure 1, see also Recommendations). Understanding what causes stress, the physiological and behavioral indicators of stress, and the extent to which stress is beneficial or negative is important to improve survival and reproduction post-release. Stress is defined as an individual's refocusing "energy on coping with a short-term threat to their survival, while lessening their long-term investments in functions such as courtship, territorial defense, reproduction, growth, and immune defense" (Busch & Hayward, 2009). Although often considered negative, stress can be beneficial to an animal, for example, when environmental cues indicating the approach of a harsher season trigger a stress response, resulting in an animal increasing its foraging in preparation for hibernation or migration (Reeder & Kramer, 2005; Romero et al., 2009). On the other hand, increased stress levels, particularly when elevated for an extended period of time causing chronic stress, can decrease the survival and reproduction rates of animals (Romero et al., 2009). For example, chronic stress can cause animals to no longer discern which threats are more important, or immediate, compared to others (Romero et al., 2009). Chronic stress can also lead to less successful or even cessation of breeding attempts, with survival prioritized over reproduction (Lattin & Kelly, 2020). Finally, chronic stress may prevent an animal from completing a full gestation or incubation period or cause the animal to display poor parenting behaviors resulting in the loss of offspring (Lattin & Kelly, 2020). However, as stress is an evolved constellation of physiological and behavioral responses enabling animals to successfully respond to acute risks or problems, complete inexperience with stress prior to reintroduction or translocation could also be detrimental to success.

In this thesis, I will build a “stress-focused” framework for making decisions about reintroduction or translocation techniques. I will, 1) outline physiological and behavioral markers of stress (Chapter 2), 2) conduct a targeted review of the literature to determine the ways in which reintroduction and translocation can be stressful or stress could be employed to assist reintroduction and translocation attempts (Chapter 3), and 3) propose recommendations for future plans of action (Chapter 4).

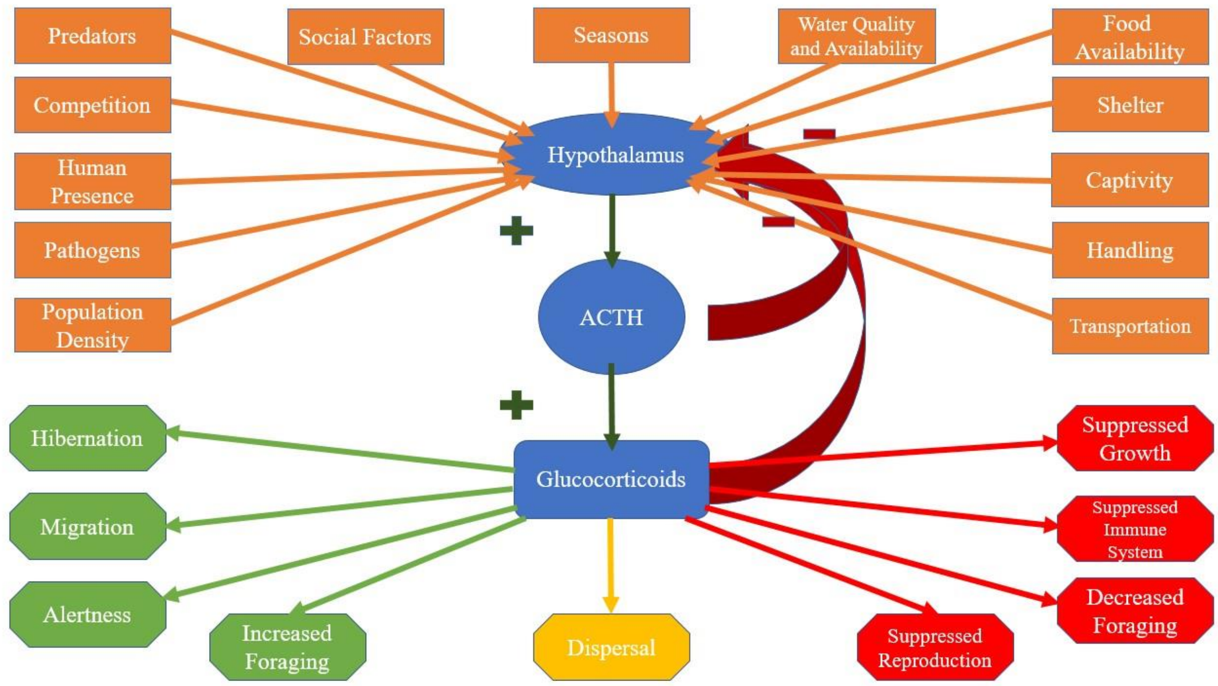

**Figure 1. Conceptual Diagram of Stress Effects Relevant to Reintroduction and Translocation.** External factors (colored orange) stimulate the production of glucocorticoids via the hypothalamic-pituitary-adrenal (HPA) or hypothalamic-pituitary-interrenal (HPI) axis (in blue). The hypothalamus stimulates the release of adrenocorticotropic hormone (ACTH) from the pituitary which stimulates the production of glucocorticoids in the adrenal glands or the interrenal cells of the head kidney. Glucocorticoid negative feedback (dark red) takes places which typically results in regulation of the stress response. The production of glucocorticoids can cause positive (green) and negative (red) responses or both (yellow) in the animal.

# Chapter 2
# Stress Physiology and Response

The hormonal response to stress in animals involves the hypothalamic-pituitary-adrenal (HPA) axis in mammals and birds, and the hypothalamic-pituitary-interrenal (HPI) axis in fishes, amphibians, and reptiles (Sopinka et al., 2015). The HPA and HPI initiate a response to an acute stressor in the hypothalamus, a region of the brain, which then releases corticotropin-releasing factor (CRF). CRF stimulates the pituitary to release adrenocorticotropic hormone (ACTH), which stimulates the adrenal gland or interrenal cells of the head kidney to produce glucocorticoids (GCs) (Sopinka et al., 2015). Glucocorticoids are a class of steroid hormones which moderate an animal's physiological and behavioral responses to environmental cues. Corticosterone is a GC found in birds, mammals, reptiles, and amphibians, while cortisol is a GC found in fishes (Sapolsky et al., 2000, as cited by Sopinka et al., 2015). The concentration of corticosterone or cortisol can be measured in various substances including blood plasma, urine, feces, saliva, hair, and water of holding tanks, and then used as biomarkers of stress in the animal (Busch & Hayward, 2009). Glucocorticoids will bind to glucocorticoid receptors (GR) found throughout the body and will initiate a torrent of physiological and behavioral changes to respond to the stressor (Sapolsky et al., 2000, as cited by Sopinka et al., 2015).

Typically, negative feedback of the HPA or HPI axis will cause GC production to cease, and the amount of circulating GCs will return to baseline levels (Sopinka et al., 2015). However, recurring elevation of GCs can cause a new chronically elevated baseline, which may influence the physiology, behavior, and fitness of the animal (Romero et al., 2009). Effects of chronic stressor exposure and long-term elevated GCs may include weight loss and reduction of growth, immunosuppression, lower reproductive success, psychological distress, and decreased survival, with weight loss being the most consistent prominent effect (Romero et al., 2009). Alternatively, some animals under chronic stress will return to the original baseline levels of GCs but lose the ability to produce a hormonal stress response, and therefore may not display an appropriate response to a subsequent stressor, which can be detrimental to the animal's survival (Sopinka et al., 2015).

Stress can have positive and negative effects on reproduction, although the positive effects tend to be understudied and require further research. When an individual is "deciding" to invest in reproduction, a negative relationship between baseline stress hormone concentration and fitness is expected (Bonier et al., 2009). This is due to individuals considered to be in good condition (i.e., low stress) being able to invest more in reproduction efforts (Bonier et al., 2009). Indeed, chronically elevated stress levels can lead to a reduction in fitness (Bonier et al., 2009). If stress levels remain near baseline levels, then there will be no interference with the reproductive effort, and in some cases, stress may enhance reproductive success (Bonier et al. 2009). For example, increases in stress levels may be beneficial once heavy investments have already been made into reproduction, because glucocorticoids can promote reallocation of energy to that reproductive effort (Bonier et al., 2009).

There are many different types of stressors which may affect wildlife, some of which may only become a factor during the reintroduction or translocation process. Potential stressors include habitat quality, food and water quality/availability, climate, noise and light pollution, environmental contaminants, predators, pathogens, population density, social factors, human disturbance, and handling, confinement, and transportation techniques (Edwards et al., 2019). Stressors are not always stand-alone and may stack together, resulting in accumulative stress (Rodgers & Gomez Isaza, 2021). For example, an animal would experience handling, confinement, and transportation stress consecutively, which would cause the animal to experience multiple stressors even before entering an unknown habitat. This may cause the stress of not knowing the location of food and water sources to affect the animal much more significantly than if the reintroduction or translocation process had not occurred. Chronic stress may occur if the stress from these experiences does not resolve quickly enough, which can have negative consequences such as immunosuppression and higher susceptibility to pathogens.

Stress in wildlife can be assessed through several different methods. Some studies use behavioral characteristics to determine stress levels. Behavioral signs of stress can be loss of appetite, pacing or thigmotaxis (hugging edges of a containment area), lower reproductive attempts or success, abnormal movement patterns, and heightened alertness (Fàbregas et al., 2020; Edwards et al., 2019). Stress levels can also be accessed by measuring stress-related hormones found in feces, urine, hair, feathers, blood, saliva samples, and water (Sheriff et al., 2011). Some of these methods, such as using feces, result in minimal disturbance to the animal; whereas collection of hair, blood, and saliva are much more invasive. Hormonal stress responses can be quantified by researchers in a controlled setting that allows quantification of levels both before (baseline) and after exposure to a stressor (Sheriff et al., 2011). Monitoring of stress hormone levels in conjunction with behavioral analysis during and after the reintroduction or translocation process should be considered when possible to understand the stress effects of the process and to determine if the animal is suffering from chronic stress in the new environment.

# Chapter 3
# Targeted Review of Literature

I conducted a targeted review of the literature to see how stress has been studied in reintroduction and translocation efforts. The goal of this study was to develop a better understanding of the challenges associated with previous reintroduction and translocation attempts due to stress and how to address them in future studies.

## Methods

I used the Web of Science database through Penn State University Libraries. I initially used the following search terms followed by several filters to remove irrelevant search results and get a manageable number of papers:

- stress affects reintroduction
- stress affects reproduction reintroduction
- stress reproduction reintroduction
- stress translocation reintroduction

Filters included removing papers on lab mice and fruit flies and refining the search with “ecology”, “environmental sciences”, “zoology”, “reproductive biology”, “evolutionary biology”, “behavioral sciences”, “fisheries”, “biodiversity conservation”, “forestry”, “ornithology” as potential topic areas. Relevant studies cited by the papers found by this search or suggested by Web of Science after the initial search were also added, while papers that turned out to be not relevant were dropped, resulting in a total of 32 papers, summarized in Appendix A.

After carefully reviewing these 32 papers, I synthesized information from all of them to develop a list of variables that likely affect stress and the success of the reintroduction or translocation attempt (“Species”, “Taxa”, “Wild/Captive”, “Stressors Present”, “Held Prior to Release”, “Hard/Soft Release”, “Age Class”, and “Time of Year”). I characterized each study for each of these variables (Appendix A), although many studies did not explicitly address or report all of these variables. In addition, I recorded “Unusual Observations” and “Beneficial Strategies” mentioned in the studies. Finally, I recorded whether I considered the study to be a “Success”, which was based on the study’s own assessment along with my assessment of whether reported survival and/or reproduction were high.

My goal was to conduct quantitative analysis of the variables that might be relevant to stress and whether a study was successful. However, studies did not consistently consider or report these variables, making such quantitative analysis difficult. In the Results, I present analyses for two variables for which there was fairly high reporting: First, whether the success of a study (using just studies deemed “successful” or “not successful”) was predicted by whether a hard or soft release was used. Second, whether the success of a study was predicted by whether animals were wild-caught or captive-reared. G-tests, which have identical results as chi-square tests for large sample sizes, but are preferred for smaller sample sizes such as here (Sokal & Rohlf, 1981), were used to test for these associations.

## Results

The set of 32 papers were fairly diverse, covering several taxa, both wild and captive bred animals, and both hard and soft releases (Figure 2). There were no clear patterns that emerged, for example the type of release did not affect the translocation or reintroduction success (G = 0.17, df = 1, p-value = 0.68, Figure 3). In addition, whether animals were wild-caught or captive-reared also did not affect success (G = 0.61, df = 1, p-value = 0.44, Figure 3). I identified several common mediators of stress in the studies such as presence of conspecifics, release techniques, age class of released animals, time of year of release, invasive species, captive-raised animal considerations, and dispersal ability. However, most of these variables were not consistently documented making it difficult to do additional quantitative comparisons. For example, 19/32 studies (59%) reported time of year, but most of these did not mention the reason for choosing that time of year or whether it may have been influential on success. Instead, in the Discussion, I describe how these variables may be relevant to stress and reintroduction or translocation success, using case studies from the literature I surveyed as supporting information.

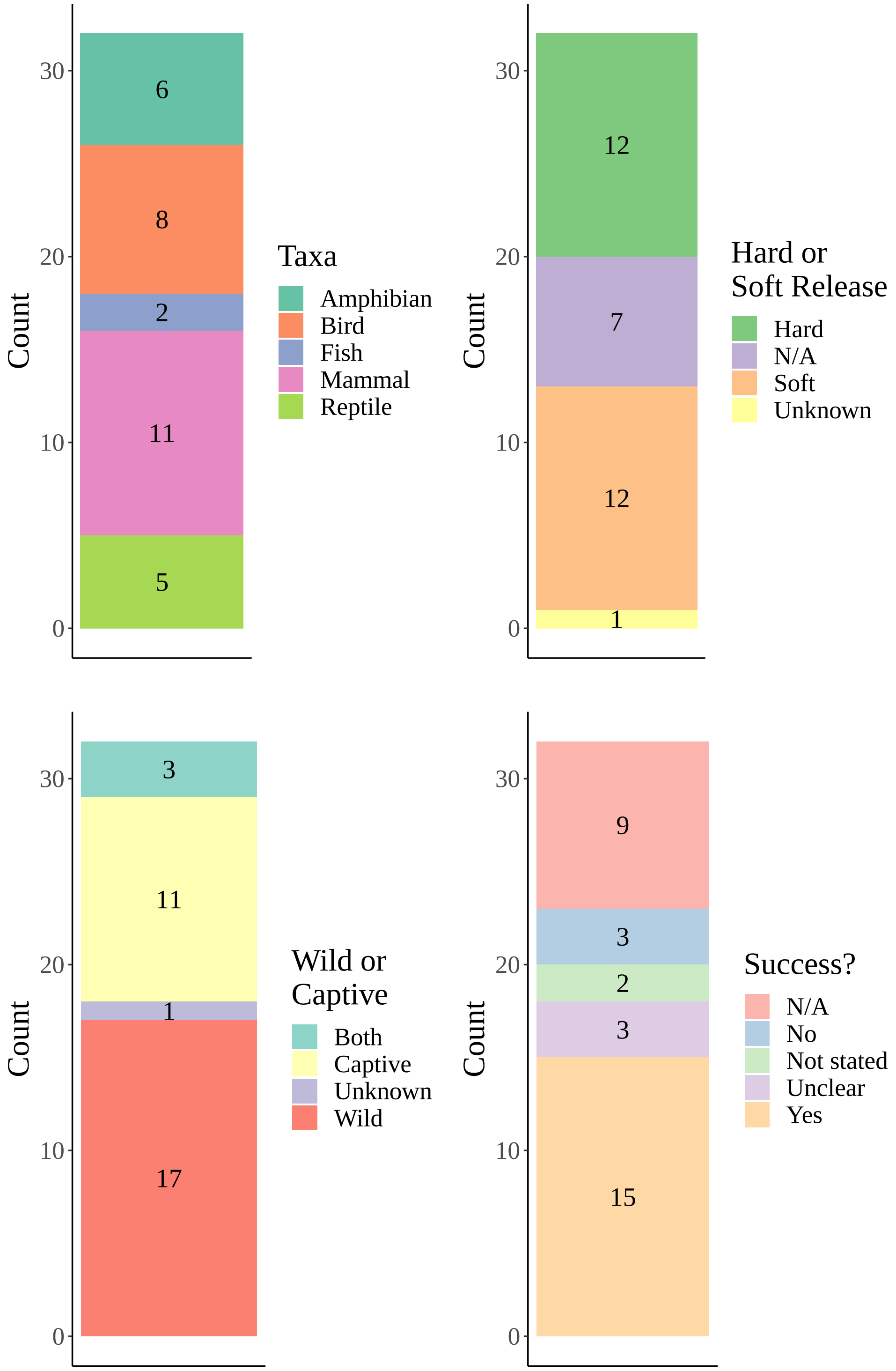

**Figure 2. Summary of Studies Surveyed.** Stacked bar plots are shown for taxa represented, whether the study was on wild-caught or captive-reared animals, whether there was a hard or soft release, and whether the study was successful or not.

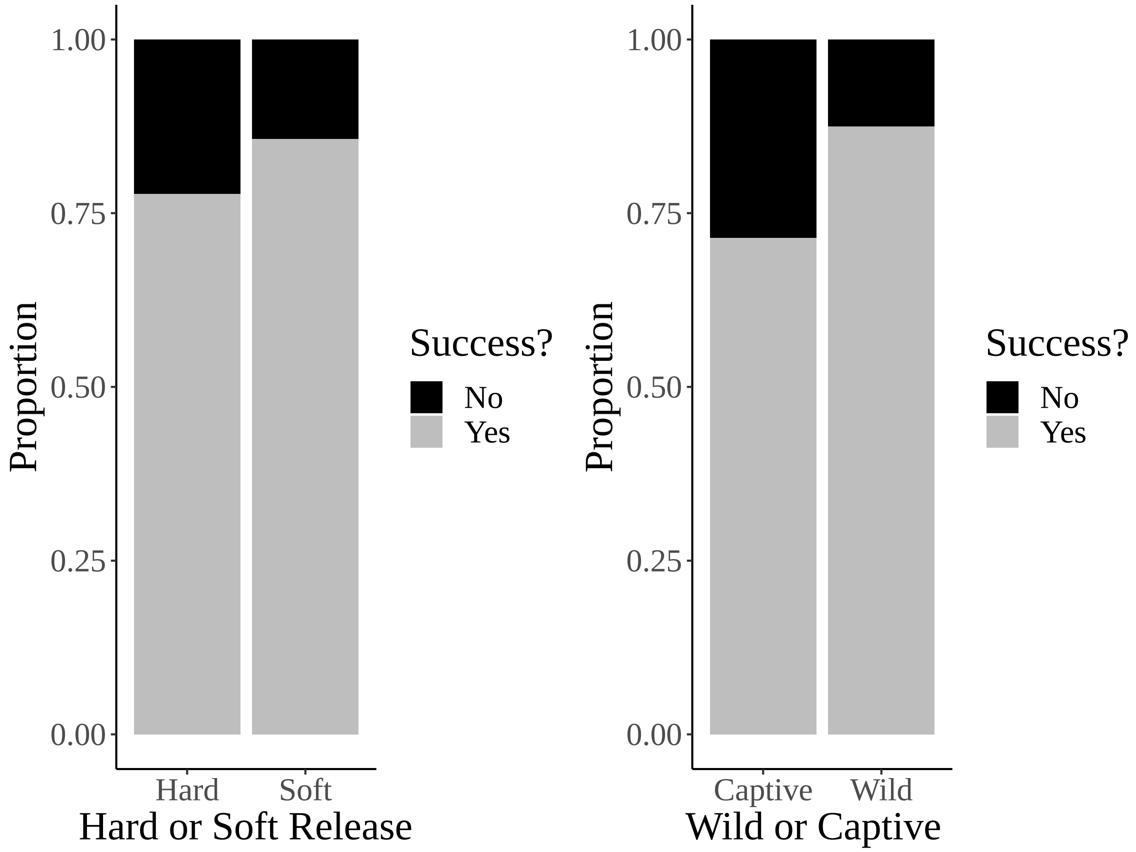

**Figure 3. Comparison of Success Based on Type of Release and Captive or Wild Individuals.** On average, whether a study used hard or soft release, or wild-caught or captive-bred animals did not affect success (P > 0.44 for both).

## Discussion

My review of the literature made it clear that there are a number of key variables that can influence stress of individuals being reintroduced or translocated that can thus affect the success of these practices (Appendix A). These include predation, lack of familiarity with a new environment, competition, lower fitness than wild counterparts, unusual parenting scenarios, anthropogenic disturbance, food and water availability, population demography, disease, injury from conspecifics, translocation process in general, capture, captivity, time of year release took place, individual personalities, poaching, carrying capacity of release site, intraspecific competition, inbreeding, isolation of new populations, and repeated handling. Some of these were explicitly mentioned and considered, while others stood out because they were not often explicitly considered but are likely important. The variables which influence stress appear to be highly species-specific (Fischer & Romero, 2019). The same variable could be particularly important in one study, but not at all in another. I will discuss these variables in more detail below with examples.

### Presence of other conspecifics

The presence of other members of the same species may increase the success of a reintroduction or translocation if resident conspecifics help new individuals find and satisfy basic needs, such as food, water, and shelter locations, reducing stress of the new individuals as they adjust to their new environment. For example, in a Timber Rattlesnake translocation study, introduced individuals were documented trailing residents, sometimes for extended periods of time. Residents at the release site were shown to help newly introduced individuals find suitable hibernacula, or shelters from the cold (Reinert & Rupert, 1999). Without a proper hibernaculum, Timber Rattlesnakes will not survive the winter months. In this study, the presence of resident snakes may have increased the survival rates of introduced individuals. Other studies did not address how presence of conspecifics affected reintroduction or translocation success.

### Release techniques

Techniques for releasing an animal for a reintroduction or translocation varies between studies with some studies using a hard release, while others use some type of soft release. Soft releases vary in design, but all include some sort of captivity in the new environment with the animal’s basic needs being accessible. Sometimes a soft release is used to allow animals to become familiar with each other when attempting to form an artificial social group (e.g., Kemp et al., 2020; Homberger et al., 2014). The duration of the soft release may vary by species and study, from a single day to several months. Both release techniques typically require some level of handling the animals which could create stress. For instance, a study on Grey Partridges found birds which had been handled for blood sampling prior to release had a 15% survival rate after the first month post-release. However, birds which were not handled for blood sampling showed a 55% survival rate one month after release (Jenni et al., 2015). The Grey Partridges which experienced blood sampling were also fitted with transmitters to be tracked using radiotelemetry, which was noted as a possible additional stressor.

Different stressors are associated with hard release and soft release techniques. Some species appear to be more successful when allowed to acclimate to their new environment as novelty and uncertainty can be stressful (Teixeira et al., 2007). However, in the literature I surveyed, the number of successful reintroduction or translocation attempts were evenly distributed between hard and soft release (Figure 3, Results). Therefore, the success of different release techniques is likely species-specific. For example, even limited time held in captivity is stressful for some species. In a study conducted on the Eastern Bettong, the lowest stress during translocation was seen when an immediate release was used as opposed to a soft release (Batson et al., 2017). The individuals released using the soft release technique, which were held in captivity between 95 and 345 days, displayed relatively high FGM (Fecal Glucocorticoid Metabolite) concentrations at release, decreasing concentrations during the first 60 days post-release, and a gradual increase during the remainder of the monitoring period. However, individuals released using the hard release technique, which were released within 24 hours of capture, displayed fairly consistent FGM concentrations across the monitoring period. In addition to species differences in stress, individuals within a species can vary in their response to stress due to differences in individual personalities (Bremner-Harrison et al, 2004); these personality differences can affect the animals' response to the release techniques used (Bremner-Harrison et al., 2004). It is important to understand how the study species will respond to soft vs. hard release in order to choose the technique which results in the least amount of stress.

### Age class of released animals

Another key factor in reintroductions and translocations is deciding the age classes of animals to be released. There are different pros and cons of selecting different age classes. For instance, it may be easier to capture a large number of younger individuals compared to adults in species that produce large numbers of offspring at one time. However, many young animals may be more prone to predation due to smaller size or less life experience, which can result in lower survival rates and failure to establish a new population (Brown et al., 2020). The higher risk of predation and general lack of life skills can in turn be stressors for juveniles. A study on Sierra Nevada Yellow-legged Frogs found survival rates were significantly lower for wild eggs, tadpoles, and subadults compared to adults (Brown et al., 2020). They noted larger individuals likely experience less stress from predation.

Juveniles may be better equipped to handle stressors in the wild if they encounter stress in captivity. For example, a study on Grey Partridges found juveniles exposed to an unpredictable food supply prior to release were twice as likely to survive post-release (Homberger et al., 2014), mimicking results from an earlier study on unpredictable feeding by parents and baby partridge physiological stress response (Homberger et al., 2013, as cited by Homberger et al., 2014). As another example, a study on Southern Mountain Yellow-legged Frogs found juveniles allowed to experience brumation prior to release appeared to have increased survival rates compared to individuals which did not experience brumation (Calatayud et al., 2020). This practice is typically avoided due to the consequences of the experienced stress from brumation, including lower growth rates, compromised immunity, and increased morbidity (Calatayud et al., 2020). However, this study found the species possessed compensatory growth mechanisms after brumation (Calatayud et al., 2020), showing that short-term costs associated with stress may balance out with the end result of increased survival in the long-term.

Benefits of choosing adults or subadults for certain species includes possessing more skills than younger individuals, such as better predator avoidance and/or foraging abilities (Brown et al., 2020). In addition, with less time needed to reach reproductive maturity, a greater proportion of released animals will likely survive to reproduce and grow the population. However, even for sexually mature individuals, short-term reproduction cannot be guaranteed once individuals experience the stressors associated with a new environment, since suppressed reproduction is commonly associated with stress. For example, in a translocation study of tigers in India, reproduction was not recorded for nearly four years post-release (Bhattacharjee et al., 2015). Even though mating was recorded, cubs were not produced by a tigress until undisturbed locations were located to successfully litter and raise cubs (Bhattacharjee et al., 2015).

A disadvantage to selecting adults or subadults, particularly from a wild population, is they may be too familiar with their original environment to successfully adapt to a new environment. For example, in the case of establishing a new colony of Fluttering Shearwater, chicks in full down with primaries half grown were found to be most suitable for translocation (Bell et al., 2005). These chicks had not yet ventured out of their burrows, ensuring they had not begun to imprint on their original site. This was important because more mature chicks who had left their burrows prior to capture were found to return to their original site for breeding instead of the translocation site. In order to establish a new colony, it was essential the Fluttering Shearwater chicks returned to the translocation site to breed to increase the population size (Bell et al., 2005). Mature individuals which have already established home ranges or territories are more prone to experience stress as they struggle to adjust to an unfamiliar habitat or attempt to return to their original location (e.g., Bell et al., 2005, Reinert & Rupert, 1999). This may become a more significant stressor depending on the time of year the release took place.

### Time of year of release

The time of year chosen to release animals may also affect the success of the study. Different seasons correspond with different stressors for each species and environment. Released animals need adequate time to adjust to their new environment prior to the harsher seasons to prevent accumulative stress from the separate stressors of holding, release into a novel location, and the more difficult seasons. For example, when releasing captive Grey Partridges, survival was drastically lower for individuals released late (mid-November) compared to individuals released early (mid-September) (Homberger et al., 2014). A two-hour reduction in daylight between the two release dates would potentially have acted as a stressor on individuals focusing on finding food and evading predators after release from captivity. Those released late also experienced a decrease in daily temperatures and food availability while energy demand, precipitation, and potentially predation pressure were all increasing. The accumulative stress of less daylight and increasing environmental adversity may have ultimately caused the lower survival in birds released late (Homberger et al., 2014).

Life history events also need to be considered when choosing the time of year for release. For example, some species hibernate or migrate for winter months, and spend time preparing for such events beforehand. If an animal is released too close to the time when an appropriate hibernaculum needs to be established, they may be less likely to survive through the winter (Reinert & Rupert, 1999). In addition, each species has a different time of year dedicated to reproduction, including courtship and the rearing of offspring. In one study, choosing to release female Fishers closer to denning season resulted in less successful reproduction post-release (Facka et al., 2016). Female Fishers released closer to their denning season were noted to have a 66% reduction in denning rate. The stress of transportation and establishing themselves in a new environment may have caused the female Fishers to allocate more energy towards their own survival instead of reproduction.

### Invasive or nonnative species

Invasive or nonnative species may act as a stressor that can frustrate reintroduction or translocation efforts. This was demonstrated in a study that found Western Mosquitofish limit recruitment of the Barrens Topminnow through predation of smaller individuals and potentially acts as a competitor species (based on laboratory trials) (Ennen et al., 2020). In this study, the stocking of the Barrens Topminnow did not significantly enhance or restore wild populations. In fact, stocking had a negative effect on Topminnow abundance when Western Mosquitofish were found in the area (Ennen et al., 2020). This shows how stress from predation and competition can have a negative effect on a reintroduced species. The Western Mosquitofish should be eradicated if possible before future stocking attempts. In the case of the Sierra Nevada Yellow-legged Frog, nonnative trout species were being stocked in reintroduction areas (Brown et al., 2020). Frogs had low apparent survival in the areas associated with the stocking of nonnative trout species. The most robust reintroduced populations were found in intermittent streams, even though this is not the typical environment associated with the Sierra Nevada Yellow-legged Frog. Newly reintroduced or translocated prey species may be especially vulnerable to predators because of the stress associated with adapting to the new environment, especially if the prey species is unfamiliar with the specific predator species, which is more likely if the predator is invasive or nonnative.

### Captive-raised animal considerations

If the individuals being released will be raised in captivity, then researchers need to consider how to best prepare them for life in the wild. For example, individuals raised in captivity will be naïve to predators. Indeed, naïve prey species such as hatchery-reared Barrens Topminnow are less fit than wild counterparts (Ennen et al., 2020). Different techniques can be implemented to improve predator recognition depending on the species (Griffin et al., 2000). Predation is a stressor not typically experienced by captive individuals. If they are not exposed to this type of stress prior to release, they may not be prepared to give an appropriate response. In a study conducted on the Mallorcan Midwife Toad, the short-term stock tadpoles displayed a stronger response to predator cues than the long-term stock tadpoles (Kraaijeveld-Smit et al., 2006). This shows the longer a species is held in captivity, especially for multiple generations, the weaker the natural response to predators may be. I think it would be beneficial to introduce prey species to predator cues, such as scent and vocalizations, along with negative stimuli while in captivity in preparation for release.

In contrast, predator species must learn how to successfully hunt prior to release since many captive facilities do not typically provide live food. Researchers need to be certain a predator species can consistently successfully hunt prior to release to increase survivability (Fàbregas et al., 2015). Even with high food availability, the inability to exploit these resources will likely add significant stress to the individual and potentially lead to death. The predator species examined in the studies I surveyed were typically wild-caught. However, this is an important factor to be considered, particularly in critically endangered species which may no longer have a wild source population for reintroductions or translocations (Fàbregas et al., 2015). For example, in a study investigating the hunting ability of captive bred South China Tigers, researchers found the tigers were overall successful in hunting free-ranging prey in semi-wild conditions, although the rate of success varied by individual (Fàbregas et al., 2015). Researchers recommended considering hunting performance as a criterion for selecting individual candidates for reintroduction.

There is evidence from at least one study that raising individuals in captivity before release can be beneficial to survival. A study on the Largetooth Sawfish found wild-caught juveniles raised in an aquarium setting grew much faster and thus attained larger size than wild counterparts (Buckley et al., 2020). The mean minimum duration of survival for the released Sawfish raised in an aquarium was 157 days, with two individuals possibly still surviving at the end of the study (they may have moved too far to be detected). The wild Sawfish, on the other hand, had a mean minimum survival duration of 58 days, without any detected as surviving at the conclusion of the study. The increased size at release of captive-reared individuals as wild same-age counterparts may have aided in survival post-release (Buckley et al., 2020).

### Dispersal ability

A final concern to consider for a reintroduction or translocation attempt is the target species’ dispersal ability. If the study species has a propensity to venture over great distances, particularly when stressed, then they may leave the study site entirely. This increases the difficulty of locating individuals to determine their health or survival status. Long-range dispersal can also limit the potential for a self-sustaining breeding population to become established within the study area. In addition, dispersal far from release sites may result in additional risks for the dispersing individuals, and result in them entering unsuitable and stressful habitats (for example, too close to human habitation).

The inability to disperse may also pose complications for conservation efforts. If a newly established population is too far from another population, then gene flow between them will not be possible, increasing the risk of extirpation of one or more of the populations (Phillips et al., 2020). In a study investigating the genetics of reintroduced populations of the Natterjack Toad, inbreeding was observed at both release sites (Phillips et al., 2020). Both study sites were surrounded by vast areas of urban development and habitat unsuitable for Natterjack Toads which likely caused isolation of both populations. The researchers recommended genetic rescue combined with the creation of additional breeding pools to increase the genetic diversity present in the populations. Inbreeding can lead to inbreeding depression, which negatively affects a population’s ability to survive and reproduce, and thus causes a decline in the population size (Allendorf et al., 2013, as cited by Phillips et al., 2020). Isolated populations affected by inbreeding are more susceptible to disease and pathogens (Spielman et al., 2004). These issues are of greater concern when newly released individuals already may be immunosuppressed from stress.

# Chapter 4
# Recommendations

There are a variety of variables to consider when developing a reintroduction or translocation study. This is a summary of the best strategies I suggest considering prior to a reintroduction or translocation attempt.

- Consider the specific species of animal selected for the study. Every species will present different challenges and risks associated with stress. The individuals selected for release will need to be prepared to handle these.
- Consider the cause of the initial decline in the study species population. Are the contributing factors still present in the environment, or have they been managed through elimination or control? If the stressor which was the source of the decline in the wild population is still present, attempts to increase or re-establish a new population may be futile.
- Consider what other species in the study area will have an impact on the study species. Will stress from competition with an invasive or nonnative species be detrimental to the study species?
- Consider the age of the individuals selected for release. Juveniles and adults will have different advantages and disadvantages associated with stressors in the new location. The advantages for the selected age class need to outweigh the disadvantages, particularly in terms of survival.
- Consider if the new population(s) will be able to recruit new individuals. Will animals from wild populations be able to move into the area? Will individuals from separate reintroduction locations be able to move between sites, or are they

isolated? Stress from the lack of gene flow will affect the new population in years to come.

- Consider what time of year the release of the animals should take place. Every species has their own set of life history events throughout the course of a year. The timing of the release needs to allow adequate time to adjust to the stress of entering the new environment to allow for the best chance of survival during stressful, harsher months as well as potential reproduction.
- Consider the type of release to be used in the study. Each species will display a different stress response to hard and soft release techniques. The type of release which results in the lowest amount of stress on the individuals should be selected, while also accounting for handling and trapping. In addition, the selected amount of time for holding the individuals in captivity will dictate the timing of trapping to fit the optimal release time.
- Consider how stress will be evaluated in the study and the possible effects it will have on the animals. Measuring stress hormones will provide the most accurate information on the fluctuation of stress in the animal. However, different techniques may increase the stress of the animal or may not be feasible post-release. Monitoring behavior avoids researchers increasing stress on the animals; however, it may not provide the most accurate results.
- Consider how the movement of the animals will be monitored after release. For example, while radiotelemetry is beneficial for tracking the dispersal and survival of individuals, the stress imposed by transmitters may be too great for some species, jeopardizing the overall success of the study.

- Consider potential intervention after release to increase the survival of struggling individuals. Some animals may not initially flourish post-release due to stress but have the potential to rebound after supplemental feeding or rehabilitation.
- Consider an adaptive management framework. Lessons learned throughout the course of a study can be applied to change study parameters as the study progresses. If a certain aspect of the study is too stressful for the animals and could potentially be improved, making adjustments may improve the overall success of the study and be preferred to waiting for a future study.

While this list is not exhaustive, the goal of these recommendations is to serve as a guide for planning a successful reintroduction or translocation study in the future based on the experiences of previous studies reviewed in this thesis.

# Appendix A

| **Number** | **Study (Author Year)** | **Species** | **Scientific Name** | **Taxa** |
|---|---|---|---|---|
| **1** | Berris et al., 2020 | Greater Bilby | *Macrotis lagotis* | Mammal (Marsupial) |
| **2** | Wilson et al., 2020 | Eastern Quoll | *Dasyurus viverrinus* | Mammal (Marsupial) |
| **3** | Bosson et al., 2013 | Eastern Gray Squirrel | *Sciurus carolinensis* | Mammal |
| **4** | Ennen et al., 2020 | North American Topminnow | *Fundulus julisia* | Fish |
| **5** | Calatayud et al., 2020 | Southern Mountain Yellow-legged Frogs | *Rana muscosa* | Amphibian |
| **6** | Liu et al., 2020 | Crested Ibis | *Nipponia nippon* | Bird |
| **7** | Kraaijeveld-Smit et al., 2006 | Mallorcan Midwife Toad | *Alytes muletensis* | Amphibian |
| **8** | Malviya et al., 2018 | Tiger | *Panthera tigris* | Mammal |
| **9** | Becker et al., 2020 | Southern Sea Otter | *Enhydra lutris nereis* | Mammal |
| **10** | Cozad et al., 2020 | Gopher Tortoise | *Gopherus polyphemus* | Reptile |
| **11** | Bradley et al., 2012 | North Island Kokako | *Callaeas wilsoni* | Bird |
| **12** | Franceschini et al., 2008 | Grevy's Zebra | *Equus grevyi* | Mammal |
| **13** | Homberger et al., 2014 | Grey Partridge | *Perdix perdix* | Bird |
| **14** | Hambler, 1994 | Giant Tortoise | *Geochelone gigantea* | Reptile |
| **15** | Bhattacharjee et al., 2015 | Tiger | *Panthera tigris* | Mammal |

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|---|---|---|---|---|
| **16** | Reinert & Rupert, 1999 | Timber Rattlesnake | *Crotalus horridus* | Reptile |
| **17** | Buckley et al., 2020 | Largetooth Sawfish | *Pristis pristis* | Fish |
| **18** | Anderson et al., 2015 | Tuatara | *Sphenodon punctatus* | Reptile |
| **19** | Jensen et al., 2019 | Western Quoll | *Dasyurus geoffroii* | Mammal (Marsupial) |
| **20** | Irwin et al., 2021 | Kakariki (Red-Fronted Parakeet) | *Cyanoramphus novaezelandiae* | Bird |
| **21** | Fàbregas et al., 2020 | White Rhinoceros | *Certatotherium simum simum* | Mammal |
| **22** | Rorabaugh et al., 2020 | Tarahumara Frog | *Rana tarahumrae* | Amphibian |
| **23** | Kemp et al., 2020 | Southern Ground-Hornbill | *Bucorvus leadbeateri* | Bird |
| **24** | Dickens et al., 2009 | Chukar | *Alectoris chukar* | Bird |
| **25** | Batson et al., 2017 | Eastern Bettong | *Bettongia gaimardi* | Mammal (Marsupial) |
| **26** | Butler et al., 2005 | Tiger Snake | *Notechis scutatus* | Reptile |
| **27** | Bell et al., 2004 | Maud Island Frog | *Leiopelma pakeka* | Amphibian |
| **28** | Phillips, 2020 | Natterjack Toad | *Epidalea calamita* | Amphibian |
| **29** | Facka et al., 2016 | Fisher | *Pekania pennanti* | Mammal |
| **30** | Bell et al., 2005 | Fluttering Shearwater | *Puffinus gavia* | Bird |
| **31** | Jenni et al., 2015 | Grey Partridge | *Perdix perdix* | Bird |
| **32** | Brown et al., 2020 | Sierra Nevada Yellow-Legged Frog | *Rana sierrae* | Amphibian |

**Appendix A (cont)**

| Number | Wild/Captive | Stressors Present | Held Prior to Release |
|---|---|---|---|
| **1** | Captive - Study Examined the Success of Previous Reintroductions | Feral Cats, Red Foxes (Predation) | N/A |
| **2** | Trial 1 - Captive and Wild; Trial 2 - Captive and Wild; Trial 3 - Wild | Predators (e.g., Red Foxes) | T1 And T3 - Released Within 48 Hours; T2 - Released 11-28 Days After Capture |
| **3** | Wild/Captive | Lack of Familiarity with New Environment, Radiocollars | No |
| **4** | Captive (Hatchery) | Competition and Predation from Western Mosquitofish, Less Fit Than Wild Counterparts | Stocked Fish Raised in Hatchery |
| **5** | Captive | Environmental Cues Triggering Brumation | Raised in Captivity |
| **6** | Captive - This Study Examined Breeding in Previous Reintroductions | Higher Nesting Failure When Polyandrous; Egg Loss Caused by Parent Treading Rather Than Food Limitation | Raised in Captivity |
| **7** | Captive | Predators | Captive-Bred |
| **8** | Wild | Water Availability, Human Presence (e.g., Forest Degradation) | N/A |
| **9** | Captive - Orphans Reared in Captivity Using Surrogate Females | El Ninos (Kelp Impacted), Overpopulation Led to Mortality Caused by Starvation, Disease, And Injuries From Other Otters | Yes, Reared in Captivity Once Found |
| **10** | Wild | Density During Translocation, Mixing Animals from | Yes, Soft Release Enclosures |

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| | | Different Populations in Soft Release Enclosures | |
| **11** | Wild | Variation Between Habitat at Capture Sites and Release Site, Translocation Process in General | Held For a Maximum of 10 Days Near Catch Site and Then Overnight Near Release Site Prior to Release |
| **12** | Wild | Captivity Showed to Have the Most Influence on FGM, Levels Returned to Baseline/Similar to Source Population 11-18 Weeks After Release | Yes, Held in Pens for a Total of 5 Weeks |
| **13** | Captive | Time of Year of Release, Personalities of Individuals in Covey | Raised in Captivity |
| **14** | Unknown | Predation From Feral Animals (Cats and Rats), Poaching, Competition | Unknown |
| **15** | Wild | Anthropogenic Disturbances (Livestock, Vehicular Traffic, Human Settlements, Timber Harvest), Water Availability and Location (Artificial Water Tanks Near Roadways) | N/A |
| **16** | Wild | Locating New Hibernacula | No |
| **17** | Wild | Not Accustomed to Natural Water Flow, Predation | Yes, Reared in Captivity After Capture, Also Allowed to Acclimate to River Water For 2 Hours and a Recovery Period of Approximately 40 Hours in Flow-Through Water Conditions Prior to Release |

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|---|---|---|---|
| **18** | Wild | Captivity Appeared to be the Main Source of Stress Since Levels Returned to Baseline/Similar to Source Population When Measured 6 or 12 Months After Release | Yes, Less Than 3 Days in Cloth Capture Bags (Holding) and Perforated Cardboard Postal Tubes (Transfer) |
| **19** | Wild | Capture and Captivity | Yes, Average of 19 Days |
| **20** | Wild - Parents Had Been Translocated, Study Focusing on Offspring | Predators (Cats, Rats, Mustelids) | Naturally Fledged |
| **21** | Captive - Orphans from Wild Raised by Humans | Captivity, Loss of Mother | Yes - Study Takes Place While Being Reared in Captivity |
| **22** | Captive and Semi-Wild | Habitat Loss, *Batrachochytrium dendrobatidis* (Bd), Chytridiomycosis, Predation (Native and Invasive) | Raised in Captivity |
| **23** | Captive, Parent-Reared | Time Of Year of Release, Predation, Disease, Anthropogenic Threat, Risk of Lead Poisoning, Risk of Electrocution | Yes, on Site Aviary For 2-61 Days |
| **24** | Wild | Captivity | No and Yes - One Group was Immediately Released After Capture, Second and Third Groups Were Held for 10 Days |
| **25** | Wild | Captivity | Yes, Delayed-Release Group Was Held in Captivity For 95-345 Days While Immediate-Release Group Were Released |

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|---|---|---|---|
| | | | Within 24 Hours of Capture |
| **26** | Wild | Drought, New Environment (Particularly Locating New Water Sources) | Unknown How Long Translocated Snakes Were Held Prior to Release (Captured as Nuisance Animals) |
| **27** | Wild | Drought (Affected Translocated Frogs and Source Population), Intraspecific Competition | No |
| **28** | Wild | Inbreeding, Translocated Populations are Isolated | N/A |
| **29** | Wild | Trapping, Captivity, Translocation, New Environment | Yes, 3-14 Days of Quarantine in California and 2-55 Days in Washington |
| **30** | Wild | Predation, Available Food | Yes, 0-36 Nights (Average 14 Nights) |
| **31** | Captive | Repeated Handling/Blood Sampling, Transmitters, Predation (Red Foxes in Particular) | Yes, 9 or 33 Hours in Release Pen Prior to Release |
| **32** | Captive | Predation, Disease (Bd), Breeding Pools Drying, Surviving Overwintering Months, New Environment | Reared in Captivity |

**Appendix A (cont)**

| **Number** | **Hard/Soft Release** | **Notable Observations** | **Beneficial Strategy** |
|---|---|---|---|
| **1** | N/A | N/A | Bilbies Were More Prevalent Without the |

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|---|---|---|---|
| | | | Presence of Red Foxes or Feral Cats. |
| **2** | Hard Release - Delayed by 2 Hours in T2 And T3 | N/A | Supplementary Food Provided in T2 (Multiple Reintroduction Trials Using Adaptive Management Framework in Study) |
| **3** | Hard Release | N/A | |
| **4** | Hard Release | Stocking Did Not Appear to Affect Wild Populations, However Stocking in Areas with Western Mosquitofish Appeared to Negatively Impact Population. | |
| **5** | Hard, Although Held Under Bucket For 10 Min Prior To Release | Frogs Which Brumated Showed Lower Growth Rates, However They Displayed Compensatory Growth Spurts After Release. | Allowed Juveniles to Brumate in Captivity Prior to Release (Higher Survival/Detection Rate After Release) |
| **6** | Soft, Acclimation Mentioned | Higher Dispersal of Released Females Resulted in Skewed Sex Ratio; Females Became Polyandrous When Typically Monogamous; High Amount of Colonial Nesting (Possibly Due to Larger Nesting Trees in Area and Abundant Food) | |
| **7** | Soft Release - Captive Breeding | Short-Term Stock Tadpoles Had Stronger Response to Predator Cues Than Long-Term Stock Tadpoles | |
| **8** | N/A | Sariska Tiger Population Showed Higher FGM Levels Than Panna Tiger Population; Panna Reproduced at Higher Rate Than Sariska. | N/A |

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|---|---|---|---|
| **9** | Soft Release - Recaptured if Showing Signs of Stress and Weight Loss, Rehabilitated and Re-Released | | Recapturing Individuals Showing Signs of Stress, Rehabilitating Them, And Then Re-Releasing Them; Recapturing Individuals Showing Greater Dispersal Helped to Prevent Large Dispersal After Second Release (Reinforced Residency Near Release Site) |
| **10** | Soft Release | Some Animals Appeared to Become "Ill" Without the Presence of Infectious Pathogens or Contaminants. Appeared to Be Caused by Social Dynamics/Population Density in Soft Release Enclosures. | Prescribed Burns Aided in Earlier Detection of Sick Tortoises While Still Alive, Lower Population Density in Enclosures |
| **11** | Soft Release | Dispersal Was Lower Than Expected for Some Individuals, Pairs Were Formed by Individuals From Different Source Populations Possibly Due to Similarity Between Vocalizations | |
| **12** | Soft Release | N/A | N/A |
| **13** | Soft Release (Held For At Least 9 Hours at Release Site Prior To Release) | Survival Varied Based on Covey, Wild Strain Did Not Survive Substantially Longer Than Domesticated Strain | Increased Survival When Food Uncertainty Was Present Prior to Release, Individuals Released Earlier in the Study Showed Higher Survival Rates |
| **14** | Unknown | | |

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| **15** | N/A | Male Which Had Previously Been Exposed to More Humans Showed Lower FGM Levels, Females Appear More Susceptible to Stress From Anthropogenic Disturbances, Successful Breeding (Producing Cubs) was Not Documented Until At Least 4 Years After Release (Higher FGM Believed to be Due to Human Presence) | |
| **16** | Hard Release | Translocated Male Observed "Pairing" with Resident Male Snake for 20 Days. | Translocated Snakes Frequently Trailed Resident Snakes |
| **17** | Soft Release | Altered Movement Behavior Compared to Wild Counterparts - Moved Slower, Displayed More Frequent Bouts of Sedentary Behavior, Occupied Deeper Water | Being Reared in Captivity Caused the Captive Sawfish to be Larger Than Wild Counterparts Which May Decrease the Likelihood of Predation |
| **18** | Hard | CORT Response Matched Source Population, CORT Concentrations Were Not Affected by Accumulative Stressors | |
| **19** | N/A | Some Individuals Did Not Show a FGM Response to Capture or Captivity (17%), Most (83%) Peaked at 24 Hours | |
| **20** | N/A | | |
| **21** | N/A | Hands-On Cohort Were Rarely Alert to Stimuli and Rarely Showed Defense Postures. Hands-On Cohort Far Less Social with Other Rhinos but Frequently Affectionate with Humans. | Hands-Off Cohort Showed More Favorable Behavior in Orphans. |
| **22** | Hard | | Results Varied by Location Due to Natural Causes. Areas with Less Predators |

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| | | | Did Appear More Successful. |
| **23** | Soft | Highly Susceptible to Human Habituation, Even in The Wild | Time of Year of Release Affected Success (Hot Dry Spring and Early Summer Less Likely to Survive), "Bush-Schools" Helped Educate Naive, Captive Bred Males (Supplementary Feeding, Naturally Structured Social Groups, Artificial Enrichment to Develop Natural Life Skills). |
| **24** | Hard | Translocated Individuals Had Decreased Baseline CORT, Reduced Capacity to Mount a CORT Response to an Acute Stressor, a Decreased Sensitivity to Negative Feedback, And Significant Weight Loss; Changes to HPA Function Occurred Quickly and Persisted Beyond the End of Exposure to Stressors. | |
| **25** | Soft - Enclosures Within New Park | Delayed-Release Group FGM Concentrations Were Relatively High at Release, Decreased Within 60 Days of Release, and Then Gradually Increased During Remainder of the Monitoring Period | Immediate-Release Group Had Consistent FGM Concentrations Across Monitoring Period |
| **26** | Hard | Translocated Snakes Exhibited Home Ranges ~6 Times Larger Than Resident Snakes, But Core Ranges Were Still of Similar Size; Translocated Snakes Were Often Found in Residential Areas Outside of The Park; Translocated Snakes Made Longer Movements Than Resident Snakes | |

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|---|---|---|---|
| **27** | Hard | | Benefited From Intraspecific Competition Release in New Environment, Higher Food Per Capita |
| **28** | N/A | Low Observed Compared to Expected Heterzygosities; However, Did Not Differ From Those Found at Source Population; Translocated Populations Appear to No Longer be Growing but May Have Reached Carrying Capacity. | |
| **29** | Hard | Females Released Later in the Study (January-March) Were Found to be Less Successful Denning. | Females Released Earlier in The Study (November-December) Were Found to be More Successful Denning (92% in California and 38% in Washington Compared to 40% in California and 11% in Washington); Fishers in California Were Held in Captivity for a Shorter Period and Were Transported Shorter Distances in Smaller Groups; And May Have Been More Familiar with Their New Environment. |
| **30** | Soft | | Individuals with Higher Mean Fledging Weights Were Significantly More Likely to Return to Colony. |
| **31** | Soft | | During First Month After Release, Individuals Held in Release Pens for 33 Hours Survived Better When Their Corticosterone Levels were Lower; However, Survival Beyond |

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|---|---|---|---|
| | | | First Month Did Not Differ Between 9 and 33 Hour Holding Period |
| **32** | Hard | Overwinter Survival of Captive Reared Frogs was Lower Than Wild Frogs; Two Largest Populations Were Found in Intermittent Streams Although Species is Typically Considered a Highly Aquatic, Perennial Water Species Requiring Deep Lakes for Breeding (May Serve as a Refuge From Predator Fishes). | Releasing Adults is More Successful Due to Apparent Low Survival of Wild Eggs, Tadpoles, and Subadults. |

**Appendix A (cont)**

| **Number** | **Age Class** | **Time Of Year** | **Success** |
|---|---|---|---|
| **1** | Subadult and Adult | N/A | Yes, If No Predators |
| **2** | T1 - Adult Males and Females; T2 and T3 - Females Only, Preferably Carrying Young | Late February-Early March (T1 - Pre-Mating; T2 And T3 - Post-Mating) | Yes |
| **3** | Adult | July-November | Yes |
| **4** | N/A | N/A | No |
| **5** | Juvenile | May and September | Yes |
| **6** | Adult | N/A | Yes |
| **7** | Juvenile (Tadpole) | N/A | |

| | | | |
|---|---|---|---|
| **8** | Adult | N/A | Yes, Successfully Bred |
| **9** | Juvenile | N/A | Yes (42/56 Successfully Reintroduced Back into Wild Population) |
| **10** | Adult and Subadult | N/A | Yes, Similar or Better Survival Rates in Comparison to Other Studies |
| **11** | Adult and Subadult | August to October | No - Lower Survival Rates Than Previous Studies |
| **12** | Adult | April | Not Stated, but Survivors Did Acclimate to New Environment |
| **13** | Juvenile | Mid-September Through Mid-November | Not Stated, but Low Survival Rate |
| **14** | Unknown | Unknown | Not Stated |
| **15** | Adult | N/A | N/A |
| **16** | Adult | Late May and Early July | No - Do Not Recommend Translocating Adult Snakes |

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|---|---|---|---|
| **17** | Juvenile | N/A | Yes - Considering None of the Wild Fish Survived |
| **18** | Adult | March and October | N/A; Only Examined CORT |
| **19** | Adult | March and April | N/A |
| **20** | Juvenile | January, April/May | Yes |
| **21** | Juvenile | N/A | N/A |
| **22** | Adult and Tadpole | June and October | Yes - in Some Areas |
| **23** | Varied, Fledgling to Adult | Varied | Yes |
| **24** | Adult | Mid July - August | N/A |
| **25** | Adult | Varied | N/A |
| **26** | Subadult and Adult | Tracked Between Spring and Fall of Following Year | Yes |
| **27** | All Age and Size Classes Included | May | Yes |
| **28** | Spawn and Tadpoles Were Initially Released; Adults Used for Genetic Testing | N/A | N/A |

| | | | |
|---|---|---|---|
| **29** | Adult; Some Captured in British Columbia Were Juveniles Due to Low Capture Success | November-December (Early) and January-March (Late) | Not Stated, but Did Have Successful Reproduction After Release |
| **30** | Fledgling | N/A | Not Stated, but Some Individuals Have Returned to Colony to Breed. Some Took 10 Years to Return So Others May Do So in the Future. |
| **31** | Juvenile | September 29-November 19 | No |
| **32** | Adult | July | Yes |

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# ACADEMIC VITA

## Education

| | |
|---|---|
| 2021 (Expected) | B.S. Wildlife and Fisheries Science, The Pennsylvania State University, University Park, PA. |

## Awards

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|---|---|
| 2015 | Gamma Sigma Delta Research Exhibition, Third Place - Undergraduate Human and Animal-Related Systems |

## Scholarships

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|---|---|
| 2012-2013 | W.J. Carnahan Alumni Scholarship; Academic Excellence Scholarship; Thevaos Honors Scholarship; Alumni Association Scholarship; Internal Scholarship Schreyer Honors |
| 2013-2014 | W.J. Carnahan Alumni Scholarship; Irvin C. Reigner Endowment; Dreibelbis Endowment Scholarship for Excellence in Agriculture; Mary & Prescott Willaman Scholarship |
| 2014-2015 | W.J. Carnahan Alumni Scholarship; Thevaos Honors Scholarship; Grant Miller Memorial Scholarship; Firth Scholarship in Agriculture; Mary & Prescott Willaman Scholarship |
| 2015-2016 | W.J. Carnahan Alumni Scholarship; Thevaos Honors Scholarship; Arthur Mitchell Honors Scholarship; Rossiter and Rapp Memorial Scholarship; Mary & Prescott Willaman Scholarship |
| 2016-2017 | Robert T. Billin Memorial Scholarship; W.J. Carnahan Alumni Scholarship; Mary & Prescott Willaman Scholarship |
| 2017-2018 | Graham Open Doors Honors Scholarship |

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| 2020-2021 | Roush & Krause Open Doors Scholarship |

**Grants**

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| 2014 | Erickson Discovery Grant |

**Presentations**

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| 2014 | Poster presentation. “A Study to Examine the Stress Levels of Arctic Ground Squirrels During a Reintroduction into Extirpated Sites in Southwest Yukon, Canada”, additional author Dr. Michael Sheriff. The Wildlife Society National Convention in Pittsburgh, PA |
| 2014 | Poster presentation. “A Study to Examine the Stress Levels of Arctic Ground Squirrels During a Reintroduction into Extirpated Sites in Southwest Yukon, Canada”, additional author Dr. Michael Sheriff. Undergraduate Exhibition |
| 2015 | Poster presentation. “A Study to Examine the Stress Levels of Arctic Ground Squirrels During a Reintroduction into Extirpated Sites in Southwest Yukon, Canada”, additional author Dr. Michael Sheriff. Gamma Sigma Delta Research Exhibition |

**Relevant work experience**

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| 2013 | Shaver’s Creek Environmental Center Raptor Center |
| 2014 (Summer) | Field Work in Canadian Yukon |
| 2014 (Fall) | Independent Studies |
| 2015 (Spring) | Independent Studies |
| 2015 (Spring) | Mammalogy Teaching Assistant |
| 2015 (Summer) | Lab Assistant |

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| 2015 (Fall) | Independent Studies |
| 2017 (Spring) | Independent Studies |

### Relevant service

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| 2013 | Habitat Restoration Project Volunteer – Clearwater Conservancy |
| 2013 | Conservation Leaders for Tomorrow (CLfT) |
| 2013 | Trail Maintenance Volunteer – Shaver's Creek Environmental Center |
| 2013-2014 | The Wildlife Society Penn State Student Chapter, Treasurer |
| 2014-2015 | Ag Advocate – Ambassador for the College of Agricultural Sciences |
| 2014-2015 | The Wildlife Society Penn State Student Chapter, President |
| 2015 (Fall) | The Wildlife Society Penn State Student Chapter, Clothing Chair |