

Ordering: The following annotated bibliographies are ordered chronologically according to the bear (*Ursus*) life cycle, including captivity. The order flows from pre-birth and post-birth to captive influences on the development of the cubs.

1

Spady, T. J., Lindburg, D. G., & Durrant, B. S. (2007). Evolution of reproductive seasonality in bears. *Mammal Review*, 37(1), 21–53. <https://doi.org/10.1111/j.1365-2907.2007.00096.x>

Summary: This review by Spady et al. (2007) focuses on the evolution of seasonal reproduction in bears (*Ursus*) and its adaptive value in modern species. The prevailing theory behind seasonality is that selection acts on reproductive cycles that co-occur with seasonal environmental conditions (births occur during periods of high resource availability). The review employs a meta-analysis of data pooled from published and unpublished (data collected by zookeepers) sources in addition to data from ecological field studies. Seasonal reproductivity is evident in both oestrus and birth timings by compiling latitude variation (climatic factors) and studbook (birthdays) data. Further evidence of seasonal reproductivity in bears was also displayed in their gonadal cycles. In females, corpora luteal dormancy and embryonic diapause reduce embryonic development, lowering the size of offspring and offsetting the initial costs of lactation. In males, testes show patterns of inactivity, preparation for mating, peak functioning, and regression, with peaks occurring in sync with the female reproductive cycle. Photoperiod (the amount of time exposed to sunlight) also induces this circannual gonadal cycle. The review concludes by discussing the impact of changing climate during the Pleistocene towards a seasonal mode in bear reproduction. It prescribes it as an evolved trait of bears cued by predictable annual cycles rather than a response to short-term environmental changes using

captive bears as comparisons since consistent food availability did not affect their reproduction. The demonstration of reproductive seasonality may have implications when considering the conservation of bear species that produce offspring only during specific periods, impacting release timings for both the cubs and mothers. Future areas of review discussed by the author include investigating how current climate trends are likely to affect the seasonality of bear reproduction.

Contribution: This review's accumulation of bear reproductive information, especially with its comparison of wild and captive populations, which showed no significant differences in their timings and behaviours, was the reason for its selection. It also advances its field by providing further evidence supporting the seasonality of bear reproductive behaviour by examining the timings of their oestrus, births, and gonadal cycles. The effect of changing climate during the Pleistocene as a heavy seasonality selector was another advancement. Possible follow-up questions to this review include investigating the genetic predisposition towards reproductive seasonality in bears.

2

Bridges, A. S., Vaughan, M. R., & Fox, J. A. (2011). Reproductive ecology of American black bears in the Alleghany Mountains of Virginia, USA. *The Journal of Wildlife Management*, 75(5), 1137–1144. <https://doi.org/10.1002/jwmg.148>

Summary: This study examines the reproductive ecology of American black bears (*Ursus americanus*) and the factors that influence them, with secluded parturition and multiannual reproductive cycles being typical complications in understanding these influences. Bridges et al.'s (2011) objectives were to quantify reproductive parameters and examine the assumptions of

current estimate methods and the factors driving them to explain observed patterns better. The study was performed by trapping, evaluating, and tracking 176 wild female bears and their 183 litters over nine years and included a hard-mast (nuts and one-seeded fruits) survey to assess the nutritional availability of the environment. Their results showed that hard-mast failure (reduced food supply) was the leading cause of missed reproductive opportunities and that periodic mast failures generated population-level reproductive failures and the synchronization of female reproductive cycles. In females that had reproduced, female age had the most significant positive effect on average litter size, with maximum reproductive output occurring at >5 years of age. The study also pointed out errors in the traditional method of measuring reproductive frequency using interbirth intervals, which overestimates reproductive frequency and is a better indicator of neonatal litter survival. The overestimation is due to overlooking complete litter loss in prior breeding seasons, mothers denning separately from their yearlings, and infertility. The significance of this study is its distinction between nutritional availability as a prime factor for successful reproductive opportunities and maternal age on the number of cubs born per litter. Therefore, researchers can develop more accurate population modelling systems by implementing these factors, enabling more precise conservation estimates. The measurement of missed reproductive opportunities rather than traditional interbirth intervals was also significant since it allows researchers to understand possible mechanisms and causations. Future research areas should reconsider how effective the use of interbirth intervals is as a measure of population parameters.

Contribution: This article was selected to demonstrate the impacts of nutritional availability and maternal age on the reproductive output of black bears. The documentation of hard-mast failure on bear reproduction was the main advancement in the field provided by this study, followed by

its inspection of current parameters used to measure reproductive frequency. It contradicts similar studies by advocating the assessment of bears' reproductive status and the nutritional availability of their environment during the summer periods rather than costly winter field den research.

3

Robbins, C. T., Ben-David, M., Fortin, J. K., & Nelson, O. L. (2012). Maternal condition determines birth date and growth of newborn bear cubs. *Journal of Mammalogy*, 93(2), 540–546. <https://doi.org/10.1644/11-MAMM-A-155.1>

Summary: This study examined the relationship between the body quality of female brown bears (*Ursus arctos*) and the growth of their cubs. Delayed implantation is a known feature of female bears meant to regulate when cubs are born to maximize the probability of reproductive success. Prior studies on other mammals have also demonstrated a correlation between food availability and female condition on pregnancy duration and birth dates. The main objective of Robbins et al. (2012) was to determine the link between maternal conditions and the size of emerging cubs with the hypothesis that females in better condition gave birth earlier, lactated longer, and produced higher quality milk than poorer condition mothers. Assessing variations in growth characteristics required the examination of six captive adult mothers placed under controlled diets to reach target body conditions. A curvilinear relationship between maternal body fat and birth dates was found, with body fat contents below 30% showing increasingly delayed births. Though mating had occurred, no cubs were born to females with less than 20% fat content. A combination of the earlier births and increased mass gain rate in cubs from fatter mothers showed increasing differences in cub masses between litters, with twins from the larger females being approximately 80% bigger than cubs from leaner mothers. The authors suggest

that earlier births allow for increased growth times in cubs which shows the significance in controlling embryo implantation to optimize fitness before, during, and after parturition. The selective pressures that limit fat accumulation due to increased predation risk in other species are less evident in bears, thus allowing them to maximize and better regulate reproductive investments. The significance of this study is its demonstration that the relationship between maternal fatness and offspring size can have multigenerational effects, leading to long-term, population-level consequences in bear reproduction.

Contribution: This article demonstrates the impacts of maternal condition on the timings and growth of cubs was the reason. It advances the study of bear reproductive ecology by utilizing fat content as an indicator of maternal condition, which influences cub timings and growth. Other studies that examine the effect of maternal states on cub development report similar results, with higher quality mothers producing cubs with higher probabilities of long-term survival. It leads to new questions regarding the impact of varying paternal conditions on cub development.

4

Rogers, L. L., McColley, L., Dalton, J., Stroner, J., Hajicek, D., Partin, A., & Burghardt, G. M. (2020). Behavior in free-living American black bear dens: Parturition, maternal care, and cub behavior. *Animals : An Open Access Journal from MDPI*, 10(7), 1123.

<https://doi.org/10.3390/ani10071123>

Summary: This study observed the natural behaviours of black bear (*Ursus americanus*) mothers and cubs during their denning periods. These typically secluded behaviours have previously been difficult to study without disturbing the bears. The altricial nature of the births ensures that mothers provide constant attention, which makes them particularly sensitive to

disturbance. The main goal of Rogers et al. (2020) was to record the occurrence and timings of specific birthing and cub care behaviours through the use of den cams by following two mother bears across six denning events. Following birth, the initial stages of cub care included the mother licking away embryonic membranes before positioning their bodies around the cubs to minimize heat loss. Nursing began three hours after birth for firstborn offspring, while subsequent litters took around 80 minutes. Yearlings also demonstrated suckling behaviours, even in the absence of milk production. The removal/consumption of cub foot pads to stimulate new growths by mothers and yearlings was another form of cub care. Den maintenance was another priority in mothers, with toilet licking (consumption of cub bodily wastes) and the designation of a latrine area for the mother. Reciprocal tongue licking and increasingly complex play as coordination improved in cubs were indicators of social skill development. The study also documented evidence of REM sleep in denning mothers and cubs, with one mother possibly dreaming as she roused from her sleep by lunging without any external disturbance. The significance of this study was the amount of data gathered, which enabled the identification of crucial wild maternal behaviours responsible for proper cub development. Implementation of these behaviours can aid in rehabilitation when rearing very young cubs in captivity. The authors suggest that future studies examine how these denning behaviours vary with maternal body condition, region, and bear species.

Contribution: The article was chosen for its documentation of bear maternal and cub behaviours during the denning periods of their lifecycles. It advances the field of bear reproductive ecology by examining behaviours within dens rather than post-den behaviours. It also contradicted other studies' interpretations of bear denning behaviours, which stated that eating, drinking, and defecation did not occur within dens. The altricial states of bear cubs lead to new questions

regarding comparisons between other altricial species such as canids and how they facilitate the proper development of their offspring.

5

Mesa-Cruz, J. B., Olfenbittel, C., Vaughan, M. R., Sajecki, J. L., & Kelly, M. J. (2020). Litter size and cub age influence weight gain and development in American black bears (*Ursus americanus*). *Journal of Mammalogy*, 101(2), 564–573.

<https://doi.org/10.1093/jmammal/gyaa009>

Summary: This study examines the energy-saving physiological processes undergone by female black bears (*Ursus americanus*) during pregnancy and the development of sensory organs in newborn cubs. Following fertilization, females utilize obligate delayed implantation of the embryos so that parturition is synchronized with hibernation, maximizing reproductive success while conserving energy. Cubs are born in an altricial state with closed eyelids and ear canals, reducing the time required for prenatal development. Mesa-Cruz et al.'s (2020) objectives were to determine the effects of offspring age and litter size on body mass (BM) and absolute and relative growth rates; the timings of sensory functionality; and the relationship between maternal diets following hibernation and cub growth. Data gathered from 129 cubs in 58 temporarily captive litters was used to meet these objectives. The study showed that BM and growth rates of twins were greater than singles or triplets up to the transition age of approximately 57 days (when hibernation ended), demonstrating the balance between competition for available milk and the need for cooperative stimulation of milk production. It also highlighted how single and triplet cubs compensated for the early low relative growth rate by growing faster than twins once the mothers resumed eating after hibernation. The immaturity of organ organization and muscular and neuronal control prompts the need for postnatal development, with cubs experiencing a delay

of around 44 days for eye and ear development while taking about 21 days to reach full functionality. The significance of understanding the variations in growth rates and timings of sensory development allows researchers to accurately assess release conditions for cubs and determine approximate ages at which human interactions may be less suitable to minimize habituation, respectively. The study highlights the need to evaluate maternal conditions and how they play a role in influencing the development of cubs.

Contribution: Key takeaways from this study include identifying a transition age in cub development that coincides with the mother's return to her regular diet following hibernation and the timings of sensory functionality. It also accurately established growth and developmental bear cub characteristics, unlike other studies where information was anecdotal or circumstantial, with direct observation of temporarily captive bears. New questions encouraged by the article include investigating how variations in the timings of maternal hibernation cessation influence cubs' growth.

6

Vickery, S. S., & Mason, G. J. (2003). Behavioral persistence in captive bears: Implications for reintroduction. *Ursus*, 14(1), 35–43.

Summary: This study examined the relationship between stereotypy frequency and behavioural persistence to determine their impact on reintroduction success in Asiatic black bears (*Ursus thibetanus*) and Malayan sun bears (*Helarctos malayanus*). Bears are more likely to develop stereotypies due to their complex feeding strategies and large home ranges, which are challenging to replicate in captivity and reduce their behavioural adaptability and attentiveness. Prior studies with voles and songbirds also demonstrated a correlation between stereotypy

frequency and an increase in behavioural persistence. Knowing that captive-reared animals face more significant risks in reintroductions, Vickery and Mason (2003) aimed to identify stereotypy types, frequency, and prevalence in bears and test the relation between stereotypy frequency and behavioural persistence. They did this through scan sampling of 29 captive bears habituated to human observation and through experimentation using conditioning with rewards, measuring how long it took the behaviour to become extinct following the absence of the reward.

Locomotion was the most common stereotypy type seen in all bears, with sun bears displaying more oral stereotypies than black bears, which showed more non-locomotory and non-oral stereotypies, reflecting the difference in natural behavioural ecology between the two species.

While no relationship was evident between the learning rate and frequency of stereotypies, it did correlate with behavioural persistence, making stereotyping individuals less suitable candidates for reintroduction. The authors suggest possible brain structural changes as a cause for this decrease in adaptability. Understanding the impacts of behavioural persistence in captive individuals is significant in increasing the probability of successful reintroductions from captivity by developing treatments or regimens to counter the reduced adaptability. These are especially necessary when supplementing populations using translocation without harming the source population is not possible. Further research is needed to offset the costs of prolonged captivity by utilizing environmental enrichment, especially in early life stages.

Contribution: The article was chosen to provide context on bear stereotypies and describe their impact on reintroduction success. It advances the field of captive bear ecology by demonstrating a positive correlation between stereotypy frequency and behavioural persistence. As an indicator of reduced adaptability, high behavioural persistence lowers the likelihood of successful

reintroductions, a conclusion shared by other studies. This conclusion leads to new lines of questioning regarding the conditions in captivity that lead to the development of stereotypes.

7

Alt, G. L., & Beecham, J. J. (1984). Reintroduction of orphaned black bear cubs into the wild. *Wildlife Society Bulletin*, 12(2), 169–174.

Summary: This study examined various reintroduction strategies in orphaned black bear (*Ursus americanus*) cubs. The main goal of Alt and Beecham (1984) was to report the results of these strategies to identify the most successful method to aid in the conservation of threatened/endangered species. The study observed 84 orphaned cub reintroductions based on four main approaches. Natal den reintroductions displayed the highest success rates with two caveats: cubs habituated to humans tended to reject the foster parents, and mothers immobilized before introducing the orphans were likely to abandon their dens and sometimes their cubs as well. If reintroductions did not occur before late April when mothers could distinguish foster cubs from actual cubs, inhibiting the sense of smell in mothers would be required to become accustomed with the orphans or separated from their own cubs for at least two hours. Treeing cubs by chasing the mother and placing orphans in or near the tree's base showed meager success rates, with the mothers killing the orphans once they returned to the tree unless there was a seven-hour delay before the reunion. Successful reintroductions in culvert trapping by housing mothers and cubs with orphans were only visible when the mothers were treated with Vicks VapoRub to inhibit their ability to distinguish between fostered and actual cubs. Pen-reared reintroductions by raising cubs in captivity till at least five months old showed few successes since most cubs became habituated to people and took part in nuisance circumstances. The significance of the study is in its application of orphan reintroductions which can be essential in

conservation approaches to mitigate declines in population levels and maintain genetic diversity within populations. Future studies must consider how variations in litter size and the environment affect the success of fostering reintroductions.

Contribution: The results of the study were essential for improving the understanding of orphan bear cub reintroductions. It demonstrated both the proper timings of reintroductions and the importance of inhibiting the mother's ability to distinguish between foster and real cubs. The article also supports other studies by prioritizing the risks of habituation to people in captive orphans, which reduces the probability of successful reintroductions. Future research opportunities could create comparative studies of fostering experiments in different species to identify common strategies and avoidances.

8

Steinmetz, R., Phumanee, W., Phoonjampa, R., & Weingdow, S. (2021). First attempt at rehabilitation of Asiatic black bear cubs to the wild in Thailand. *Journal of Threatened Taxa*, 13(6), 18411–18418. <https://doi.org/10.11609/jott.6343.13.6.18411-18418>

Summary: This article examined the effectiveness of soft release methods in black bear (*Ursus thibetanus*) cubs. Hard or soft release strategies are the main categories of reintroductions. Soft releases allow individuals to become used to their new environment before release by spending time in the habitat with supplemental feeding, while hard releases involve no acclimation. The primary goal of Steinmetz et al. (2021) was to refine future rehabilitation procedures and document cub behaviours in a natural environment. The study involved two orphaned bear cubs fed a supplemental diet and whatever they could forage over nine months. Two caretakers acted as surrogate mothers by walking with the cubs to develop their foraging skills and familiarity

with the environment. The combination of the supplemental and foraged diets seemed to allow the bears to grow steadily with an estimated weight gain of 4.7kg/month. By the end of the rehabilitation period, they were physically fit for release, meaning that there was no significantly harmful effect on the bears' health due to the mixed diet. The bear walks allowed for closer observations into natural bear behaviours and displayed a transition from predominantly play behaviours early in the experiment to more foraging behaviours and an increased wariness of humans towards its end. It also demonstrated that slight variations in soft release methods did not significantly affect release success when the rehabilitation minimizes habituation to humans. This article is significant in providing more data regarding the behaviours of black bear cubs in captivity and how human-assisted soft release methods allow for suitable growing and release conditions. It also bridges the gap in documentation regarding bear rehabilitation in Asia, which will increase the probability of success for subsequent reintroductions. Future research areas should investigate how the release site conditions affect rehabilitation success and performing assisted bear walks.

Contribution: This article provides evidence of the effectiveness of soft release methods in a field that currently lacks the necessary data to objectively select the best form of rehabilitation and release, which was the reasoning behind its selection. Demonstration of a steady growth rate with the mixed diet and the implementation of bear walks to allow the cubs to acclimatize to their environment supported previous studies, showing the advantages of soft release methods. It also leads to new questions regarding other human-led activities promoting natural/instinctive animal behaviours in captive organisms.

Blair, C. D., Muller, L. I., Clark, J. D., & Stiver, W. H. (2020). Survival and conflict behavior of American black bears after rehabilitation. *The Journal of Wildlife Management*, 84(1), 75–84. <https://doi.org/10.1002/jwmg.21783>

Summary: This study assessed the survival and post-release conflict status of rehabilitated, orphaned black bear (*Ursus americanus*) cubs and yearlings. Habitat alterations exacerbate the causes of orphaning and include abandonment, vehicular collisions, hunting, and natural disasters. Rectifying this can involve non-intervention, humane euthanasia, reuniting bears with their biological mothers or fostering, permanent captivity, and rehabilitation for later release. The prime benefits of rehabilitation are the recovery of declining bear populations and quicker reintroductions when a mother is unavailable to take care of them. The main objectives of Blair et al. (2020) were to use GPS tracking and known fate models to estimate first-year survival, identify critical variables responsible for survival, cause-specific mortality, and conflict behaviours of 42 rehabilitated black bear cubs and yearlings. Their methods involved tracking tagged bears following a hard-release procedure. The study results showed that the survival of both rehabilitated cubs and yearlings was not significantly different from wild individuals and that releases near capture sites reduced post-release displacement (reduced nuisance probability). Conflict behaviours were similar between wild and rehabilitated individuals. However, conflict was primarily seen in cubs from mothers with known histories of nuisance, likely due to social learning by cubs observing their mothers foraging for human food. The implementation of hard-release methods also enabled the measurement of its impact on survival rates, which lend credence to its viability. The study's main conclusions were that rehabilitation was a suitable alternative for reintroducing orphaned and injured bear cubs, with higher success rates seen in the spring release of yearlings. These results are significant for developing conservation

strategies that implement the reintroduction of captive individuals to maximize success probabilities by releasing cubs at appropriate times in their life cycle. The authors suggest following similarly aged, released bears for longer durations to measure reproductive ability better.

Contribution: Understanding the outcomes of rehabilitation on the survival and conflict behaviours of released bears is vital to developing functional reintroduction procedures. The study advances this field by providing evidence of the success of rehabilitation through comparisons with wild individuals. This study also contradicts current theories by observing a positive relationship between distance travelled and survival and maternal histories being a better predictor of conflict behaviours than food availability. These contradictions lead to new questions about alternative factors that are responsible for conflict behaviours in cubs.

10

Beecham, J. J., De Gabriel Hernando, M., Karamanlidis, A. A., Beausoleil, R. A., Burgess, K., Jeong, D.-H., Binks, M., Bereczky, L., Ashraf, N. V. K., Skripova, K., Rhodin, L., Auger, J., & Lee, B.-K. (2015). Management implications for releasing orphaned, captive-reared bears back to the wild. *The Journal of Wildlife Management*, 79(8), 1327–1336.

<https://doi.org/10.1002/jwmg.941>

Summary: This study examined the post-release conditions of captive-reared American (*Ursus americanus*) and Asiatic (*Ursus thibetanus*) black and brown (*Ursus arctos*) bears, with concerns regarding captive-rearing that include habituation to people. Beecham et al.'s (2015) objectives were to document the post-release survival, cause of mortality, human-bear conflicts, movement, and reproduction of orphaned, captive-reared bears released as yearlings. The study catalogued

550 bears with GPS collars in areas coinciding with each species' respective ranges. American black and brown bears had undergone hard-release methods, but Asiatic black bears required soft-release strategies because they inhabit areas with high predation. The study demonstrated that survival rates of captive-reared bears were similar to wild populations, with American black bears being most affected by hunting pressures and brown bears by intraspecific predation. Bears orphaned at younger ages (<8 months) with increasing release weight showed higher survival rates, indicating a balance between larger masses and a lack of prior experience. However, heavier weights for bears orphaned beyond eight months showed increases in mortality, likely due to hunter preference for weightier bears. Since Asiatic black bears are a protected species, it probably contributed to higher survival rates than brown and American black bears, with conflict removals and illegal kills being the highest mortality cases. Movements of American black and brown bears and first reproduction age and litter sizes between black bears also demonstrated no significant differences between wild and captive-reared bears. The results of this study were significant in proving the success of captive-reared reintroductions since many characteristics were similar between wild and captive-reared individuals. These reintroductions are essential for conservation programs to maintain genetic diversity in small, isolated populations, restore bears to previously occupied habitats, and create inquiries regarding reintroductions' genetic and population-level effects.

Contribution: This study was chosen to provide evidence of successful reintroductions of captive-reared individuals. By demonstrating these successes, the study advances the field of bear reintroductions by compiling data from individuals tracked over more prolonged periods, allowing for more accurate assessments of current reintroduction strategies. Many studies support the similarities in survival, movements, and reproductive ability between wild and

captive-reared individuals. These similarities lead to new questions about the reintroductions of other captive species and the similarities or differences compared to their respective wild counterparts.