

ARTICLE

Rehabilitating infant eastern cottontails (*Sylvilagus floridanus*): a robust scoping review of the relevant literature published in Canada and the United States

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Abstract

The objective of this review is to describe the current available literature on rehabilitated eastern cottontails (*Sylvilagus floridanus*) in Canada and the United States to determine gaps in our knowledge, how the state of available literature compares to other wildlife species, and what aspects of rehabilitative care are covered. To meet the objectives, eligible sources must have included eastern cottontails that have entered rehabilitation. Thirty-six articles from 31 different authors were within the inclusion and outside the exclusion criteria for analysis. Results show a lack of information related to eastern cottontails in 80% (4/5) of categories and significant variation in protocols, with most being related to feeding. The lack of published scientific literature and protocol variation could be contributing to knowledge gaps within the field of rehabilitation.

BIO

Pauline Kosmal, MSc is a PhD student studying infant eastern cottontail survival and welfare. She is committed to improving rehabilitative practices and bridging the gap between the scientific and rehabilitative community. NWRA committee member.

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Introduction

Research in the field of wildlife rehabilitation is relatively limited. With a growing need for wildlife rehabilitation programs (Miller 2012), it is critical we continuously refine our knowledge for the benefit of the animals for which we rehabilitate. Importantly, wildlife rehabilitators provide a large amount of information on the health of rescued individuals, but this is often unused by the scientific community (Trocini et al. 2008). That said, while there are many factors contributing to a rehabilitator's practice, it is possible some variation in protocols can be explained by the large proportion of data that go unanalyzed. The increasing amount of negative impact humans

have on wildlife has affected the need for wildlife rehabilitators and increased the necessity for animal care and the education of the public (Miller 2012).

Wildlife rehabilitation is defined by the NWRA and the IWRC as “the treatment and temporary care of injured, diseased, and displaced indigenous animals, and the subsequent release of healthy animals to appropriate habitats in the wild” (Miller & Schlieps 2021). From this definition, it is apparent that efforts in wildlife rehabilitation place value on the individual animal. However, wildlife rehabilitation is also beneficial on a species level, frequently for conservation or protection (Carstairs et al. 2019; Gartrell et al. 2019).

For this study, eastern cottontails are a representative model for a commonly admitted and high mortality

Keywords

Eastern cottontail; review; *sylvilagus*; wildlife rehabilitation

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Abbreviations

EC: eyes closed
EO: eyes open
WOA: weeks of age
DOA: days of age
NWRA: National Wildlife Rehabilitators Association
IWRC: International Wildlife Rehabilitation Council
PRISMA-Scr: Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews
WRB: Wildlife Rehabilitation Bulletin
PROC ANOVA: Analysis of variance procedure
PROC GLIMMIX: Generalized mixed linear models procedure
COVTEST: test for covariance parameters

species. With the common goal of rehabilitation being the successful reintegration of wildlife into their natural environments, it is important to create evidence-informed practices to increase the chance of survival. Wildlife rehabilitators should possess a thorough understanding of an animal's natural history to minimize stress. While most strive to replicate their natural environment as closely as possible, this is often challenging. Some centers implement natural history training to help guide staff and volunteers, and more information can be gathered through conferences, presentations, or other works, but much of this information is passed from individual to individual (Pospisil 2014). This said, there are various types of rehabilitators who possess important knowledge, and this knowledge may not always be widely communicated; therefore, previous publications may not reflect current practice, and new information and practices may not be transferred to other rehabilitators.

Eastern cottontails are altricial—born hairless and with eyes closed. They are dependent on their mothers for several weeks after birth. Mother rabbits (does) usually frequent their nest twice a day, once at dawn and once at dusk to feed a high fat milk (Tseng 2019). In addition, newborn eastern cottontails are considered to have a “sterile gut,” meaning no detectable gut bacteria are present in the large and small intestines at birth (Cañas-Rodríguez & Williams Smith 1966; Van Camp et al. 1994; Savietto et al. 2020). During the first few weeks of life it is important for an eastern cottontail to develop a healthy gut, primarily through consumption of their mother's cecotropes, (Johnson-Delaney 2006; Akande 2015) and at this time they are especially susceptible to disease (Combes et al. 2011).

Other aspects of eastern cottontail rehabilitation to consider include housing/shelter and behavior. Eastern cottontails mature rapidly and begin to leave their nest around 3–5 WOA (Tseng 2019) and disperse from their nest around 6–7 WOA, which are considerations for rehabilitators when determining appropriate release age. Additionally, release sites should be chosen based on resource availability. Eastern cottontails should be released in areas with shrub coverage, their preferred coverage type (Chapman & Litvaitis 2004; Cheeseman et al. 2019; Kilpatrick & Goodie 2020), and diverse vegetation to support their seasonal diet requirements (Chapman & Litvaitis 2004; Tseng 2019; Abu Baker et al. 2021). Eastern cottontails in habitats with appropriate coverage and vegetation have smaller home ranges (distance traveled away from their nest), and therefore expend less energy and are less likely to be predated than those with larger home ranges (Bond et al. 2004; Hunt et al. 2014). A large range of release rates for eastern cottontails have been reported and not all literature provides

in-depth detail regarding the various aspects covered in rehabilitation. From this, further challenge is created when comparing methods for raising rehabilitated eastern cottontails to determine best practice.

This review will determine the current availability of scientific literature on eastern cottontail rehabilitation and the breadth of information the literature covers. Potential applications include an increase in the validity of practices and suggestions on areas for improvement in wildlife welfare in the revision of current rehabilitation protocols. The primary questions driving this scoping review are:

1. What aspects of eastern cottontail rehabilitation does the literature focus on?

Secondary questions are identified as follows:

2. Can we identify variation in protocol recommendations among studies reporting eastern cottontail rehabilitation methods?
3. Where does this literature come from?
4. How does this literature compare to other literature on commonly rehabilitated wildlife species?

Determining the aspects (or stages) of eastern cottontail rehabilitation which the literature focuses on is critically important for identifying gaps in our knowledge. Further, establishing variation in protocols, study locations, and how eastern cottontail literature compares to other species, will allow us to determine the breadth of these gaps. This review does not seek to assess a hypothesis, but rather determine the state of the available literature to eastern cottontail caretakers, making a scoping review the most appropriate format for this analysis.

Materials and methods

This scoping review was conducted using a PRISMA-ScR checklist. General use and methods are outlined in (McGowan et al. 2020).

Literature focus

The search terms “Eastern cottontail” and “rehabilitation” were entered into Google Scholar. Three hundred and seventeen results appeared and 28 fit the criteria for this review. The focus of this study was to determine the practices used or suggested for raising eastern cottontails in wildlife rehabilitation. While the introduction provides a broad overview of eastern cottontail natural history, and various general concerns of wildlife rehabilitators, the search terms for the major portion of the text were selected based on relevance to the research questions. Previous search terms included “rabbit” or “*Sylvilagus*

floridanus”, other synonyms of rehabilitation (“rehabilitate”, “rehabilitated,” “rehabilitates,” “rehabilitating,” “treatment”); however, these terms yielded a higher proportion of irrelevant results. Google Scholar provided the largest scope and the literature covered ranged from 1991 to 2020 without additional filtering. All relevant material resulting from the listed search was written in English and exclusive to North America; therefore, no further refinement was required. Sources of information were excluded if the rehabilitated animals in the study were not cottontails or if unrelated to rehabilitation (i.e., were wild caught). Most of the excluded articles were based on habitat restoration or translocation. All sources that presented information on rehabilitated cottontails were included.

A second search was conducted in the WRB. Articles that included the keywords “cottontail” or “eastern cottontail” were included. Articles were found in the archives and the “lagomorph” section was reviewed for content. Six relevant articles appeared from this search, with two already included in Google Scholar. The available content included journal articles exclusively from the years 2004 to 2016. No further refinement was required as all articles fell within the previously listed inclusion criteria.

A third and final search was conducted in the IWRC archives. The archives from the last 30 years were searched for the term “cottontail.” An additional six articles were provided, with one already appearing in Google Scholar and one being outdated (from 1983). Therefore, four articles from the IWRC archives were included in this review, from 1992 to 2021, making a total number of 36 articles analyzed. Other databases such as Web of Science, Biological Sciences, PubMed and CabDirect were cross-referenced to ensure all relevant literature was covered in these searches. The selection process was recorded, and a flow chart was created using Adobe

Illustrator Software®. Once selected, the articles were analyzed and charted based on the included information.

Categories were defined as:

1. Admission details
2. Euthanasia details
3. Housing details
4. Feeding details
5. Outcome and release details

All forms of publications were accepted to broaden the scope of the review; information was presented as peer-reviewed journal articles ($n = 17$), theses ($n = 6$), guides ($n = 6$), book chapters ($n = 3$), case studies ($n = 2$), a literature review ($n = 1$), and a pilot study ($n = 1$) (Fig. 1). The most recent Google Scholar, WRB and IWRC searches occurred in January 2022. The included sources had four main objectives: disease surveillance and treatment, general care guidelines, assessing the reason for admission, or assessing outcome. A COVTEST was run to determine if the primary focus of the literature influenced the level of detail, and they were included as random effects.

Rationale

Each of the categories influence eastern cottontail welfare and survival, which is their purpose of inclusion in this study.

Admission. We identified the primary focus for eight of the 36 studies to be related to reason for admission; therefore, it was expected this would be one of the most detailed categories. Previous research has identified biological variables including weight class, reason for admission, presence or absence of injuries or illness, severity of the injury or illness (if present), if entering care as a singleton or in a group, and

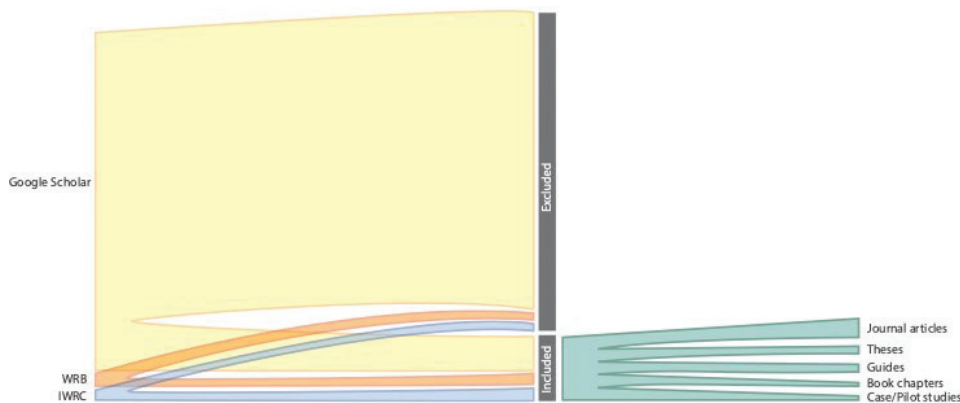


Fig. 1 Manual screening process of the literature described in this scoping review.

if there was prior human intervention (Principati et al. 2020) that affects the survivability of eastern cottontails while in care. Therefore, this provides the rationale to include admission as a category. Because the state of eastern cottontails on admission depicts the type of care they will begin to receive (Burton & Doblar 2004; Garrigan et al. 2016; Loyd et al. 2017; McRuer et al. 2017; Long et al. 2020; Paul & Friend 2020; Timm & Kime 2020; Hanson et al. 2021), we can expect admission information to be included in detail in the literature.

Euthanasia. Rehabilitator attitudes and beliefs may influence their decision to euthanize or attempt rehabilitative care of a species (McGaughey 2012; Pospisil 2014). It is considered the ethical responsibility of a rehabilitator to euthanize an animal when warranted (Dubois 2003). Rehabilitators are required to consider the costs and benefits to each individual animal's welfare (Kirkwood & Best 1998) and regulations are in place that describe when euthanasia is necessary, usually in cases of severe illness or injury (Miller & Schlieps 2021). However, variation in euthanasia protocols is likely, as rehabilitators may be reluctant to attempt rehabilitative care based on previous experience or the center's capacity. For example, due to low success rates, some rehabilitators may opt to euthanize eyes-closed eastern cottontails (usually <40 g) (Principati et al. 2020; Kosmal 2021). For these reasons, euthanasia was included as a category.

Housing. While most agree eastern cottontails are housed in quiet areas with a place to hide, the location (indoors or outdoors), type of enrichment, and if there should be a conditioning period are variable among rehabilitation centers. A conditioning period or outdoor housing may help an eastern cottontail become familiarized with their surroundings and forage in a safer environment prior to being released (Cherney & Nieves 1991; Diehl & Stokhaug 2012; Ford & Dubé 2019), but it is unknown whether this period is beneficial to released eastern cottontails in the long term. Housing infant eastern cottontails indoors in quiet areas only could be a way to minimize stress while in care (Reese 1992a; Jijón et al. 2007; Oberly 2015; Paul & Friend 2017; Santos 2018; Tseng 2019). As housing can have a significant effect on an eastern cottontail's welfare and potentially their outcome, it is important to be included in this analysis.

Feeding. The prevalence of gastrointestinal illness in eastern cottontails may be influenced by the milk formula used (Oberly 2015; Paul & Friend 2017: 201, 2019), hence the feeding category was included. Gastrointestinal diseases, most commonly clostridial enterotoxemia and coccidiosis (Paul & Friend 2019), can create lesions in

the cecum and colon, ultimately resulting in nutrient malabsorption and potentially death (Keel & Songer 2006; Vela et al. 2010; Cattadori et al. 2016). Common milk replacers used in rehabilitation include Esbilac™, Kitten Milk Replacer (KMR®) and Fox Valley™ (FV), with additives to replicate maternal milk as closely as possible. However, rabbit milk is specialized in the sense that it contains milk oil, a composition of short-chain fatty acids which are used in the development of a young cottontail's gut (Maertens et al. 2010). Explained by the low survival and the instances of diarrhea and bloat with the use of non-rabbit milk replacers, it is possible these formulas are not meeting the dietary requirements of growing cottontails. However, with inconsistencies among other aspects of rehabilitation, determining the leading cause (and how to reduce the instance of acute death) is still poorly understood.

Outcome and release. As with admission, eight out of 36 studies identified primarily focused on outcome. Specifically, the factors that may contribute to an eastern cottontail's disposition. The age (or weight) at which eastern cottontails are deemed ready for release can differ depending on the rehabilitation center to which they were admitted, which can affect results. Eastern cottontails over 200 g are less likely to be brought in due to cat attacks (Paul & Friend 2020); therefore, it was recommended to release at (or above) this weight. However, some argue keeping young eastern cottontails in care for this length of time may cause additional stress (King 2007; Principati et al. 2020). Although important to consider, release rate may not be the best estimator of a rehabilitation center's success due to variations in protocols. Therefore, release rate may not be an effective indicator of quality of life and welfare. Outcome and release category were included in this analysis.

Within the categories, all studies containing data ($n = 26$)—primary or secondary studies—were charted and colored based on their level of inclusion. Within the five categories (admission, euthanasia, housing, feeding, and release), results were transformed into numeric data, on a scale of zero to three, where a score of zero meant no details were provided in the respective category, and a score of three meant all analyzed details were provided. This data then underwent an analysis of variance using the Ryan-Einot-Gabriel-Welsch multiple range (REGWQ) function under the PROC ANOVA procedure to determine which means were significantly different. The REGWQ function is used for non-continuous data with more than two means for comparison (SAS Institute Inc. 2015). A significant difference for one of the means was revealed (p -value < 0.001); therefore, a second analysis using the

PROC GLIMMIX procedure was carried out to determine which mean(s) were/was different.

Protocol recommendation variation

All studies that contained recommended protocols ($n=19$) were charted and analyzed for variation. Disease treatment was not included in the protocol analysis. Veterinarians establish treatment protocols, and therefore one study discussing treatment of gastrointestinal illness (Paul & Friend 2021) was excluded from this part of the analysis. Practices were assessed based on the Standards for Wildlife Rehabilitation (Miller & Schlieps 2021), and known natural history traits.

Study locations

Study locations were collected from all resulting publications, then highlighted on a map of Canada and the United States. The publication city, province/state, and country were recorded. Map locations of the various sources were plotted using Adobe Illustrator Software®.

Context

As the number of scientific sources was limited, an analysis of the available literature on two additional commonly admitted species was conducted—the eastern grey squirrel (*Sciurus carolinensis*) and the Virginia opossum (*Didelphis virginiana*). The resulting numbers further indicate the lack of published scientific research within the field of rehabilitation and contextualize the number of publications on rehabilitated eastern cottontails. A summary of the selection criteria and the results were recorded.

Results

Of the 36 studies analyzed, four main purposes within the literature were identified. Eight had a primary focus on admission, eight on outcome, 10 on general care and 10 on disease surveillance. Importantly, results of the COVTEST revealed the primary focus had a significant effect on the outcome ($p < 0.0001$), meaning the reason for writing the text influences the level of detail provided.

Literature focus

The 26 studies with included data revealed eastern cottontails were the most admitted species, with cat attacks being the most common reason for admission (Carter 2009; Garrigan et al. 2016; Loyd et al. 2017; McRuer et al. 2017; Long et al. 2020; Paul & Friend 2020; Timm & Kime 2020; Hanson et al. 2021). Details covered by the literature included the frequency ($n = 36$), the criteria

($n = 28$), and methods/protocols ($n = 17$). The number of details covered is higher than the number of articles included in the search as some articles included several details from multiple categories.

These details were defined as follows:

1. Frequency (how often eastern cottontails were admitted, euthanized, offered enrichment, fed in a day, and released)
2. Criteria (reason for eastern cottontail admission, euthanasia, housing location, weaning, and releasing)
3. Methods or protocols (how each of the categories were offered)

Of all the categories, the literature was most likely to include details related to admission and the least likely to include details related to housing (Table 1). Results of the multiple means comparison revealed a statistically significant difference in the level of admission details (p -value < 0.0001) when compared to other detail categories (Table 2). No additional differences in mean inclusion level were found. Admission details had the highest mean inclusion level (1.58/3), while housing details had the lowest (0.42/3).

Protocol recommendation variation

Of the 36 papers included in the analysis, 19 discussed protocol recommendations for eastern cottontail rehabilitators. Most categories included two to three different protocols except for the number of suggested feedings (seven listed protocols ranging from one to five feeds per day) and the release weight (four listed protocols ranging from 100 to 220 g or more). Different protocols were created based on apparent success, and although some studies discussed various options, some evidence supporting practices were anecdotal.

Admission details. Four different categories were identified with regard to admissions—handling procedures, latency period before handling, rehydrating method on admission, and warming method on admission (Table 3a). Some rehabilitators reported wearing gloves when in contact with eastern cottontails to avoid the transmission of zoonotic disease (Taylor 2002; Casey 2008; Tseng 2019), whereas another source explained handling should be done with bare hands during feeding to keep them comfortable with rehabilitators (King 2007). In addition, a slight variation in when to first handle the animal is reported; one rehabilitator recommends waiting one to two hours after intake (before triage) to reduce stress (King 2007), whereas others recommend weighing and starting triage as soon as possible to assess for injury (Diehl & Stokhaug 2012; Gage & Duerr 2019).

Table 1 Heat map representing the amount of information provided by literature on rehabilitated eastern cottontails in five different categories.

Component	Admission	Euthanasia	Housing	Feeding	Outcome
Frequency	22	2	1	5	10
Criteria	14	6	5	4	4
Methods or protocols	6	6	3	6	1

Table 2 Mean level of detail in five categories to describe the state of literature on rehabilitated eastern cottontails.

Detail	Mean level	F-value	Pr > t
Admission	1.54	10.06	<0.0001*
Euthanasia	0.62		
Housing	0.38		
Feeding	0.62		
Release	0.58		

*Indicates a significant difference.

Table 3 An overview of protocol recommendations from scientific sources discussing eastern cottontail rehabilitation in five areas (a) Admission protocols (b) Euthanasia protocols (c) Housing protocols (d) Feeding protocols and (e) Release protocols.

(a) Admission			
Category	Details	Source	Assessment of practice*
Handling	Handle with gloves	(Taylor 2002; Casey 2008; Tseng 2019)	It is recommended to handle all wild animals with gloves to reduce the instances of disease spread. However, there is no evidence for or against the use of bare hands to acclimate eastern cottontails to their handlers during feeding to reduce stress.
	Handle with bare hands	(King 2007)	
	Capture with small towel	(Taylor 2002)	
Latency period	Wait 1–2 hours before handling	(King 2007)	Animals with emergent issues should be treated immediately. When minor injuries are present, it is appropriate to complete a full assessment later; however, there is no specified amount of time. The severity of the injury and the number of animals requiring assessment likely contribute to the length of the latency period.
	Perform quick assessment as soon as possible	(Diehl & Stokhaug 2012; Gage & Duerr 2019)	
Rehydration method	Intraperitoneal fluids	(Belisle 2004)	While intraperitoneal fluids allow for large volumes of fluids to be delivered to animals, they are not recommended for use in rabbits due to risk of gut perforation. Subcutaneous fluid delivery is appropriate in small quantities (Ager 2017)
	Subcutaneous fluids	(Reese 1992b; King 2007; Gage & Duerr 2019; Tseng 2019)	
Warming method	Warm in incubator	(Cherney & Nieves 1991; Taylor 2002)	Incubators, heating pads and heating lamps are all appropriate for use; however, heating pads and lamps should not be placed under/over the entire housing area.
	Warm with heating pad or heating lamp	(King 2007; Taylor 2002; Oberly 2015; Tseng 2019)	

(Continued)

Table 3 (Continued) An overview of protocol recommendations from scientific sources discussing eastern cottontail rehabilitation in five areas (a) Admission protocols (b) Euthanasia protocols (c) Housing protocols (d) Feeding protocols and (e) Release protocols.

(b) Euthanasia			
Category	Details	Source	Assessment of practice*
Injuries	Severe injury	(Oberly 2015; McRuer et al. 2017; Paul & Friend 2017; Santos 2018; Principati et al. 2020)	Euthanasia decisions are based on the individual prognosis of the animal. Full euthanasia criteria can be found in (Miller & Schlieps 2021).
Illness	Severe illness	(Oberly 2015; Paul & Friend 2017; Santos 2018)	Rehabilitators may decide to euthanize neonate (newborn) eastern cottontails based on poor prognosis.
Development	Eyes closed/ under 40 g	(Principati et al. 2020; Kosmal 2021)	
(c) Housing			
Category	Details	Source	Assessment of practice*
Enclosure type	House in cages/ pens	(Cherney & Nieves 1991; Reese 1992a; Belisle 2004; Jijón et al. 2007; King 2007; Casey 2008; Oberly 2015; Tseng 2019; Kosmal 2021)	Boxes or small containers are often used for young mammals. Aquariums appear less frequently used; however, are still appropriate. Young cottontails must be kept warm and housing environments should have barriers and a place to hide.
	House in aquarium	(Taylor 2002)	
Location	Indoor to start, transfer when weaned	(Cherney & Nieves 1991; Diehl & Stokhaug 2012; Ford & Dubé 2020)	Neonate and injured or ill eastern cottontails should not be housed outdoors. There is no research to support the effect of a preconditioning period on post-release success.
	House indoors only	(Reese 1992a, b; Jijón et al. 2007; Oberly 2015; Paul & Friend 2017; Santos 2018; Tseng 2019; Kosmal 2021)	
	House outdoors with lamps (unless <50 g)	(King 2007)	
(d) Feeding			
Category	Details	Source	Assessment of practice*
Method	Tube feed only	(Oberly 2015; Principati et al. 2020; Kosmal 2021)	Both tube and syringe feeding are common practice in wildlife rehabilitation. Tube feeding allows for a controlled amount of formula to be delivered; however, there is a risk of mis-tubing (delivering formula to the lungs via the trachea) or puncturing the stomach.
	Syringe feed unless failure to thrive	(Reese 1992a; Taylor 2002; King 2007)	
	Syringe feed only	(Paul & Friend 2017; Tseng 2019)	
Formula Type	FV and/or KMR™ as main component	(King 2007; Paul & Friend 2017; Tseng 2019)	Some studies reported a comparison between two formulas. However, a comparison on the health and survival of young cottontails on all types of formulas used by rehabilitators under the same conditions has not been conducted. In general, eastern cottontails should consume milk that is high in fat, protein, and energy (Oberly 2015; Principati et al. 2020; Kosmal 2021).
	Wombaroo® rabbit milk replacer	(Kosmal 2021)	
	Starter/Ultra as main component	(Oberly 2015)	
	6:4 Esbilac™ and MultiMilk™ as main component	(Taylor 2002; Tseng 2019)	
	Esbilac™ or KMR™ as main component with MultiMilk™	(Reese 1992a)	

(Continued)

Table 3 (Continued) An overview of protocol recommendations from scientific sources discussing eastern cottontail rehabilitation in five areas (a) Admission protocols (b) Euthanasia protocols (c) Housing protocols (d) Feeding protocols and (e) Release protocols.

(d) Feeding			
Category	Details	Source	Assessment of practice*
Additives	Cecotropes	(Taylor 2002; Belisle 2004; King 2007)	There is no evidence to support eastern cottontail health or survival is improved with the use of cecotropes. However, gut bacteria development may be altered if cecotropes are not received in the early life stages (Johnson-Delaney 2006; Combes et al. 2011; Akande 2015).
	Probiotics (<i>Lactobacillus acidophilus</i>)	(Belisle 2004; King 2007)	While no studies have proven the efficiency of <i>Lactobacillus acidophilus</i> in eastern cottontails, studies in domestic rabbits have proven supplementation with <i>Lactobacillus acidophilus</i> reduced instance of disease and death (Colombino et al. 2022)
Dilution	Offer Pedialyte® at every feed	(Gage & Duerr 2019)	Eastern cottontails require milk high in fat, protein, and energy to support rapid growth. There is no evidence to support dilution with Pedialyte® is optimal. Rehabilitators may provide Pedialyte® for hydration support, or to assist with the transition from milk to formula.
	Gradual dilution starting with electrolytes or Pedialyte®	(Reese 1992a; Taylor 2002; King 2007; Oberly 2015; Santos 2018; Tseng 2019)	
Number of feedings	3–4 feedings for EC 2 for EO	(Cherney & Nieves 1991)	The number of feedings likely depends on the amount of formula received by eastern cottontails, and the calorie content of the formula. In the wild, eastern cottontails feed twice a day for approximately five minutes (Casteel 1966; Anderson et al. 1975)
	4–5 feeds from 0–1 WOA, 3–4 from 1–2 WOA, 2–3 from 2–3 WOA, 1–2 from 3–4 WOA	(King 2007)	
	2 feedings until weaning	(Oberly 2015)	
	1–2 feeds until weaning	(Principati et al. 2020)	
	2–3 for EC, 1–2 for EO	(Taylor 2002)	
Weaning age	However, many it takes to get to the required caloric intake	(Tseng 2019)	Typically, wild eastern cottontails are weaned around 3–4 WOA. Weaning weight is variable depending on birth weight and growth rate. Birth weight in eastern cottontails is geographically and individually variable (Swihart 1984).
	2–5 depending on age and condition 3–6 WOA	(Reese 1992b)	
Weaning weight	Start at 10 DOA	(Taylor 2002; Belisle 2004; King 2007; Santos 2018)	Typically, wild eastern cottontails are weaned around 3–4 WOA. Weaning weight is variable depending on birth weight and growth rate. Birth weight in eastern cottontails is geographically and individually variable (Swihart 1984).
	Start at 2 WOA	(Oberly 2015; Principati et al. 2020)	
Introducing solids	70–140 g	(Cherney & Nieves 1991; Principati et al. 2020)	Currently, there is no evidence to support the gradual introduction of solids.
	115 g+	(Oberly 2015; Kosmal 2021)	
Introducing solids	Gradual	(Reese 1992a; King 2007; Santos 2018)	Currently, there is no evidence to support the gradual introduction of solids.
	All at once	(Cherney & Nieves 1991; Taylor 2002; Oberly 2015; Tseng 2019; Kosmal 2021)	

(Continued)

Table 3 (Continued) An overview of protocol recommendations from scientific sources discussing eastern cottontail rehabilitation in five areas (a) Admission protocols (b) Euthanasia protocols (c) Housing protocols (d) Feeding protocols and (e) Release protocols.

(e) Release			
Category	Details	Source	Assessment of practice*
Release weight	100–200 g	(Diehl & Stokhaug 2012; Ford & Dubé 2019)	Currently there is no post-release research to identify optimal release weight or age. To qualify for release, animals need to be healthy, self-feeding, and display appropriate behaviors.
	120 g+	(King 2007; Tseng 2019; Principati et al. 2020)	
	125–140 g	(Kosmal 2021)	
	150 g+	(Reese 1992a; Oberly 2015)	
	220 g+	(Paul & Friend 2020)	
Release age	Over 3 weeks	(Kosmal 2021)	In general, wildlife should be acclimated to their natural environment; however, like above mentioned, there is no post-release research to identify the relevance of a preconditioning period. There is no specification for optimal release times for eastern cottontails in the literature. However, eastern cottontails are a crepuscular species (most active at dawn and dusk), and therefore this may be optimal release time of day.
	4–5 weeks	(Cherney & Nieves 1991; Tseng 2019)	
	4–7 weeks	(Diehl & Stokhaug 2012)	
	4–8 weeks	(Ford & Dubé 2019)	
Pre-release conditioning	Acclimate before release	(Diehl & Stokhaug 2012; Ford & Dubé 2019; Tseng 2019)	In general, wildlife should be acclimated to their natural environment; however, like above mentioned, there is no post-release research to identify the relevance of a preconditioning period.
	Conditioning/ acclimation not necessary	(Cherney & Nieves 1991)	
Time of day	Morning	(King 2007; Tseng 2019)	There is no specification for optimal release times for eastern cottontails in the literature. However, eastern cottontails are a crepuscular species (most active at dawn and dusk), and therefore this may be optimal release time of day.
	Afternoon	(Cherney & Nieves 1991)	
	Evening	(Diehl & Stokhaug 2012)	

*General assessment of practice based on Standards for Wildlife Rehabilitation (Miller & Schlieps 2021). In some instances, there was minimal to no evidence to support the use of one practice in favor of another.

It is assumed that eastern cottontails with severe injuries were euthanized on admission to avoid unnecessary suffering. Once the assessment is complete, two different options for rehydrating and warming are discussed. One older study suggests the best method for rehydration is intraperitoneal fluids (and lists subcutaneous a second-best method) (Belisle 2004), whereas others recommend subcutaneous fluids (Reese 1992b; King 2007; Gage & Duerr 2019; Tseng 2019) only. Finally, it is recommended to warm eastern cottontails in an incubator (Cherney & Nieves 1991; Taylor 2002) or by placing a heating pad or heating lamp under or over (respectively) half the cage (Taylor 2002; King 2007; Oberly 2015; Tseng 2019). It is also noted that a rehabilitator recommends placing eastern cottontails <50 g in an incubator set to 85–90°F (29–32°C), regardless of body temperature (King 2007). It is also important to note, in accordance with the NWRA and IWRC standards of care (Miller & Schlieps 2021), individuals admitted with head trauma would not be placed in an incubator to avoid further complications.

Euthanasia details. Euthanasia protocols were the least variable (Table 3b). This is likely attributed to the fact that

wildlife rehabilitators are expected to follow federal and municipal laws and perform euthanasia under the guidance of a veterinarian. All studies mentioning euthanasia agree that eastern cottontails with severe illness (Oberly 2015; Paul & Friend 2017; Principati et al. 2020) and severe injury (Oberly 2015; McRuer et al. 2017; Santos 2018) should be euthanized. Finally, due to poor success rate, two studies discuss their protocol to euthanize eastern cottontails with closed eyes (<40 g) (Principati et al. 2020; Kosmal 2021).

Housing details. In the previous analysis, housing details were the least commonly included. However, consensus with housing details is noted (Table 3c). Most rehabilitation centers suggest housing eastern cottontails in cages/pens (Cherney & Nieves 1991; Reese 1992a; Belisle 2004; Jijón et al. 2007; King 2007; Casey 2008; Oberly 2015; Tseng 2019; Kosmal 2021) while one recommends aquariums/tanks (Taylor 2002). In addition, it is preferred to house eastern cottontails indoors only (Reese 1992a, b; Jijón et al. 2007; Oberly 2015; Paul & Friend 2017; Santos 2018; Tseng 2019; Kosmal 2021), with three studies recommending transferring outdoors prior to release

for pre-conditioning (Cherney & Nieves 1991; Diehl & Stokhaug 2012; Ford & Dubé 2019). Only one study recommends housing outdoors with heat lamps (except those <50 g) (King 2007).

Feeding details. Feeding protocols presented in the analyzed studies revealed the most variation in practice (Table 3d). Five studies considered tube feeding to be an appropriate method for efficiently delivering milk to eastern cottontails either for all feedings (Oberly 2015; Principati et al. 2020; Kosmal 2021) or during failure to thrive (not gaining weight, or not growing at an appropriate rate) (Taylor 2002; King 2007), whereas three indicated they syringe-fed only (Reese 1992a; Paul & Friend 2017; Tseng 2019). This variation could be due to the number of admissions—centers with a greater number may be required to tube feed to provide care simultaneously. A range of recommended formulas are reported (see formula type in Table 3d), with suggested additives such as cecotropes (Taylor 2002; Belisle 2004; King 2007; Tseng 2019) or probiotics (mainly *Lactobacillus acidophilus*) (Belisle 2004; King 2007). The number of feedings ranges anywhere from one to five times per day and it is typically recommended to gradually introduce formula by replacing part of the formula with electrolytes or Pedialyte® for at least the first feeding (Reese 1992b; Taylor 2002; King 2007; Oberly 2015; Santos 2018; Tseng 2019). Notably, the number of feedings is based on eastern cottontail natural history. Rabbit milk is considerably rich and high in energy for rapid development (Maertens et al. 2010); therefore, to meet caloric needs, more feedings may be required during rehabilitative care. The timing of the start and end of weaning (transitioning from milk to solid feed) is highly disputed among studies, with age and weight ranging from 10 days of age to six WOA and 70–140 g. Finally, some studies gradually introduced solid foods, introducing one type at a time (Reese 1992a; King 2007; Santos 2018) while others introduced all types of solid food (grasses, greens, fruits, vegetables, and/or pellets) at once (Cherney & Nieves 1991; Taylor 2002; Oberly 2015; Tseng 2019).

Release details. The common goal for released animals is successful reintegration—in which the process could be contributing to the success of eastern cottontails once back in the wild. Determining the timing of release is variable among studies (Table 3e) and overall, could affect post-release success. Recommended release rates range from 100 g (King 2007; Principati et al. 2020) to greater than 220 g (Paul & Friend 2020). As age is significantly correlated with weight, it makes sense that this would vary as well; however, most studies agree

eastern cottontails should be a minimum of four WOA (Cherney & Nieves 1991; Diehl & Stokhaug 2012; Ford & Dubé 2019), with one study stating release over three WOA (Kosmal 2021). A preconditioning period (controlled outdoor acclimation period prior to release) may help eastern cottontails transition to their natural environment prior to release (Diehl & Stokhaug 2012; Ford & Dubé 2019; Tseng 2019). However, it is also suggested that preconditioning may not be necessary (Cherney & Nieves 1991). The final disputed aspect for release is the timing, with two studies recommending the morning (King 2007; Tseng 2019), one recommending the afternoon (Cherney & Nieves 1991) and one, the evening (Diehl & Stokhaug 2012).

Study locations

Results show there is a lack of literature originating from Canadian wildlife institutions. Fourteen locations are covered in the 36 resulting articles with four studies from Canada and 30 from the United States (Fig. 2) (two studies were published as eBooks and therefore did not have a listed location). Importantly, the research conducted in Canada covers only three of the four provinces in which eastern cottontails reside.

Context

To contextualize the amount of available literature, additional searches were conducted on other commonly admitted species to wildlife rehabilitation centers in North America: the eastern grey squirrel and the Virginia opossum. For the first additional search, the terms (“eastern grey squirrel” or “eastern gray squirrel”) and “rehabilitation” were entered into Google Scholar. Both forms of spelling were used to capture all relevant articles. Two hundred and sixty results appeared and 25 fit the criteria for this review. The “rodents and insectivores” section of the WRB provided nine additional papers, with five fitting the inclusion criteria for a total of 30 studies. When “Virginia opossum” and “rehabilitation” were entered into Google Scholar, 230 articles appeared with 22 fitting the inclusion criteria. Finally, the “marsupial” section of WRB offered three additional papers, all of which were included for a total of 25 studies.

Discussion

The objective of this review was to describe the previously published literature on rehabilitated eastern cottontails in Canada and the United States to determine knowledge gaps, how the state of available literature compares to the



Fig. 2 Map of locations in which literature on rehabilitated eastern cottontails was published in Canada and the United States from 1991–2021.

literature on other wildlife species, and what aspects of rehabilitative care are discussed. The results of this study reveal significant gaps in the published literature from which rehabilitators could share rehabilitated eastern cottontail protocols. However, knowledge among rehabilitators is often communicated orally, and therefore these practices may have not been documented in this review. The existing literature primarily focused on the reason for admission and its impact on release. Release rates of eastern cottontails are highly variable and reported as 35% (Oberly 2015; Garrigan et al. 2016), 39% (Santos 2018), 45% (Hanson et al. 2021), 47% (Frink 2020), and 33 and 53% (depending on the milk replacer used) (Paul & Friend 2017). Some variation in the release rates can be explained by the different protocols characterized in

this study; however, rehabilitator perspectives, experiences, and opinions play a key role in the care of wildlife (Pospisil 2014). It is widely accepted that animals with severe injury and/or illness may need to be euthanized. However, except for severe enterotoxemia (Paul & Friend 2019) and spinal injuries (Paul & Friend 2017; Principati et al. 2020), “severe” is not specifically defined in the literature. Standards of care reveal euthanasia decisions are made on admission, but assessments are ongoing and an indication of a decline in health may also warrant euthanasia (Miller & Schlieps 2021). While rehabilitators consider the welfare of animals on an ongoing basis, the perception of “severe” trauma may be influenced by individual rehabilitator attitudes and beliefs about likely outcomes of treatment. This is further explained by how

personal experience may influence euthanasia decisions (McGaughey 2012; Pospisil 2014). To fully understand which factors contribute to eastern cottontail outcome, further exploration is required.

The housing protocols were the least described in the literature. While the reason for this is not known, it may be due to the high level of consensus in this category. The other category with little variation is euthanasia. The category which was the most extensively covered was admission and the category with the most variation was feeding, followed by release. Reportedly, eastern cottontails should be weaned between 70 and 140 g and an appropriate release time for eastern cottontails was determined to be three to six WOA, but 100 to over 220 g. Some variation may be explained by the inclusion of weight as a minimum requirement because it is highly variable among individual cottontails.

The available literature on the rehabilitation of infant eastern cottontails may not fully represent the breadth of practices or the relative proportion of cottontails entering rehabilitation centers in Canada and the United States. Therefore, further studies are required to fully understand the influence of individual rehabilitation practices and measures of health that may affect eastern cottontail outcomes. Analysis of rehabilitation data could help identify the practices that lead to more successful outcomes, in addition to further applications highlighted in Trocini et al. (2008). While wildlife rehabilitation has advanced and practices have improved, from this study, we were able to identify and characterize the key knowledge gaps in the literature on rehabilitating eastern cottontails. Addressing these gaps could result in the improvement of eastern cottontail survival in creating best practices for wildlife rehabilitators.

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