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Hand-rearing Roe deer *Capreolus capreolus*: practice and research potential

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Four ♀ Roe deer *Capreolus capreolus* were hand-reared and released into a 10 ha enclosed natural habitat. This paper describes the hand-rearing procedure, nutrition and development, which we compare with other documented cases. We illustrate the handling techniques that enabled us to maintain a close relationship with the hand-reared Roe deer in their adulthood and study them under semi-free-ranging conditions. The benefits of conducting research with hand-reared Roe deer are described, together with possible biases that must be taken into consideration when planning a research programme. The Roe deer were hand-reared in order to conduct a detailed feasibility study for the Roe deer reintroduction programme in Israel, where they have been locally extinct for 100 years.

Key-words: development; fawns; feasibility study; free-ranging; hand-rearing; Israel; nutrition; reintroduction; roe deer.

INTRODUCTION

Hand-reared animals have been used in various studies, including foraging behaviour (Spalinger *et al*., 1997), thermal cover (Cook *et al*., 1998), development (Birgersson *et al*., 1998) and improving capture and handling techniques (Hastings *et al*., 1992). In all these cases, research was carried out in captivity, but there are also rarer cases where research was carried out with free-ranging hand-reared animals, such as Kudu *Tragelaphus strepsiceros* (Owen, 1994) and Sitka black-tailed deer *Odocoileus hemionus sitkensis* (Parker *et al*., 1999). However, hand-rearing a wild animal is usually a challenging process, which can have a very low success rate, and therefore requires comprehensive knowledge and fine care (Robbins, 1993). Therefore, documentation of the hand-rearing procedures is valuable.

Roe deer *Capreolus capreolus* are considered difficult to hand-rear (Prior, 1968, 1995; Wölfel, 1993). Wölfel (1993) reported that the success rate of hand-rearing newly born fawns that have not yet consumed milk is close to zero and that of a 1 week-old fawn is $<50\%$. Nevertheless, several research programmes have hand-reared Roe deer for various purposes, such as analysis of diet composition and nutrition (Holand, 1994; Tixier *et al*., 1997, 1998), monitoring stress response (Dehnhard *et al*., 2001) and reproductive physiology (Hoffman *et al*., 1978; Lambert, 2002). In addition, because the Roe deer is a common species of Europe (Andersen, Duncan & Linnell, 1998), injured and orphaned fawns are often picked up by humans in an attempt to nurse and thus save them (Putman, 1990).

Roe deer have been locally extinct in the east-Mediterranean as a result of hunting and habitat loss since the beginning of the 19th century (in Jordan: Quemsiyeh *et al*., 1996) and 20th century (in Lebanon, Israel, Syria and Iraq: Aharoni 1943; Harrison & Bates, 1991). In 1991, the Israeli Nature and National Parks Protection Authority (INNPPA) established a Roe deer breeding colony in the Hai-Bar Carmel Reserve (close to the city of Haifa), with 27 deer brought from France, Italy and Hungary. The breeding colony failed to grow, with only 28 Roe deer in 2004, which was the highest number ever

achieved. The low survival of fawns was one of the observed problems in the breeding colony. Small-scale releases began in 1996 with high mortality during transport and release. Approximately 24–29 Roe deer were released by 2006. Some Roe deer survived and reproduced but the reintroduction has not been successful so far.

The difficulties encountered in the captive-breeding programme and reintroduction attempts prompted us to find a way to study the Roe deer under natural conditions. Roe deer are extremely flighty and are difficult to observe under free-ranging conditions and do not become tame in captivity. Hand-rearing was chosen to enable close observations under semi-free-ranging conditions. The hand-reared Roe deer were to remain a part of the breeding colony and the hand-rearing procedure was under license from the INNPPA and the ethics committee of the University of Haifa. Here, we describe the hand-rearing procedure of Roe deer, which includes a review of the available literature, and emphasize the potential of conducting research under free-ranging conditions.

METHODS

Finding and handling the newborn Roe deer

Roe deer give birth around May–June (Andersen, Duncan & Linnell, 1998); therefore, a daily search of the Roe deer's enclosure was carried out from the middle of April. Newly born fawns are very difficult to detect; they are camouflaged and lie motionless for the first week. To reduce stress, and avoid the risk of mastitis in mothers, we only collected fawns that had siblings. We chose to rear only ♀♀ to avoid the problem of aggressive behaviour in hand-reared ♂♂ during the rut (Pinter, 1963; Putman, 1990; Prior, 1995). We began the hand-rearing process at an early age to ensure that the fawns adapt easily to their keeper (Pinter, 1963). When the infants were located, they were carried in the arms of the keeper and taken to the keeper's house. Two fawns, daughters of two different mothers and one father, were hand-reared in 2001 and two more, offspring of the same parents, in 2002.

Nutrition

We separated the fawns when they were 2–3 days old, allowing them sufficient time to obtain colostrum from their mother's milk. If the fawns are younger, colostrum must be added to their milk (Sams *et al*., 1996; Lambert, 2002). Providing an appropriate milk substitute is one of the most important factors when hand-rearing (Robbins, 1993). Analyses of Roe deer milk composition are presented in Table 1. Inappropriate milk substitutes may result in severe diarrhoea (Wayre, 1967; Bradley, 1971; Wölfel, 1993), dehydration (Bradley, 1971), stunted growth (Bradley, 1971; Baugatz *et al*., 1997) and death (Miller *et al*., 2001; R. Putman, pers. comm.). Therefore, efforts have been made to find a good substitute for Roe deer milk (Drescher-Kaden *et al*., 1972, 1974).

We fed the fawns with a lamb milk replacement (Sanolac, Schils, Holland). The nutritional values of the milk replacement were 24% protein, 15% casein, 19% fat, 0·2% fibre, 6·5% ash, 1% calcium, 0·7% phosphorus and vitamins A, D3 and E. We prepared 45 g of milk powder in 250 ml water at 39 °C, which is the average body temperature of an adult Roe deer (Lambert, 2002). The milk also contained Rumansin (16 mg kg^{-1}), an antibiotic used as a growth promoter. During feeding sessions, milk was fed *ad libitum* using a standard human baby bottle (see also Wayre, 1967), which was sterilized daily. We compared daily milk consumption between our hand-reared fawns and four

COMPONENTS	PINTER (1963)	TREICHLER *ET AL.* (1974)	CSAPÓ *ET AL.* (1987)
Dry matter	20·4	24·3	24
Protein	8·8	9·4	7
Lactose	3·8	3·5	
Fat	6·7	6·6	11·9

Table 1. Major nutritional values of Roe deer *Capreolus capreolus* milk, as analysed by different authors (g/100 g milk).

fawns hand-reared in Aberdeen, Scotland (1.3 ♂.♀), which were known to be healthy adults with high reproductive success (R. Lambert, unpubl. data). R. Lambert hand-reared the Roe deer on a 19% concentrated commercial lamb milk substitute (Lambert, 2002).

During all feeding sessions, the anus was massaged gently with a moistened finger, in order to stimulate defaecation. Roe deer will occasionally consume small amounts of earth, which may lead to digestion problems (R. Putman, pers. comm.). Our fawns spent most of the day outdoors, where they had free access to earth and vegetation.

Development

The fawns were weighed opportunistically until maturity, but most frequently during their first month. The growth rate during the first 10 weeks was analysed with a linear regression (see Andersen, Gaillard & San José, 1998 and Portier *et al*., 2000). We compared the relative growth rate (RGR) between our hand-reared fawns, and the four fawns hand-reared in Scotland (R. Lambert, unpubl. data). $\mathrm{RGR} = (\ln W_2 - \ln W_1)/(t_2 - t_1)$, where W_1 and W_2 are the fawns' body masses at times t_1 and t_2, respectively. We also compared the growth rate of our hand-reared Roe deer with their mother-reared siblings in subsequent years during the first week of life (while it was possible to approach them).

Veterinary care

Ectoparasites were removed manually from the day the fawns arrived and into adulthood. Rectal temperature was measured on a regular basis during the first 2 weeks. Throughout the hand-rearing period, several health issues were addressed (e.g. diarrhoea, fever, ear infection) and were overcome with veterinary assistance. Monthly medical examinations continued until the age of 2–2·5 months. By that time, it became too difficult to restrain the Roe deer during veterinarian checkups. The keeper, from then on, evaluated the health of the animals and sought veterinary advice when necessary. The fawns were given supplementary vitamins and stomach bacteria (Probiotics, Primalac Star-Labs/Forage Research Inc.) every day until they were 2 months old, and whenever antibiotics were needed (to support the digestive tract flora).

Handling

During the hand-rearing period, the Roe deer were kept in the keeper's house with access to a fenced garden. They were rarely left alone for more than 3 hours at a time. From the age of 1 month, the Roe deer were taken on daily walks outdoors. They were encouraged to follow by routine calling. Trying to habituate them to the leash from a young age failed. With a leash attached, they would either try to fight it off or would simply not move. Therefore, they were allowed to walk freely.

At the age of 6–8 months, the Roe deer were gradually introduced into an outside enclosure. After a period of 1 month, the Roe deer were released into the study site, which is a fenced forested site of 10 ha (within the range of natural home range sizes of ♀ Roe deer in nature: San José & Lovari, 1998, but see Andersen, Duncan & Linnell, 1998). It was necessary to restrict the Roe deer to a fenced site to prevent the risk of predation, illegal hunting and car accidents. The keeper maintained contact with the deer on a daily basis to retain the relationship that was required to be able to work with them under free-ranging conditions. Occasionally, the mature Roe deer were left alone for up to 12 days.

RESULTS

Health and development

When the fawns were hungry, they stood up and whined loudly. The fawns needed to be fed every 2 hours during the first few days and nights, but they fiercely rejected the bottle. To encourage feeding, they were seated and the nipple was placed into their mouth. Slowly, they began to suck on the nipple until they could drink while standing

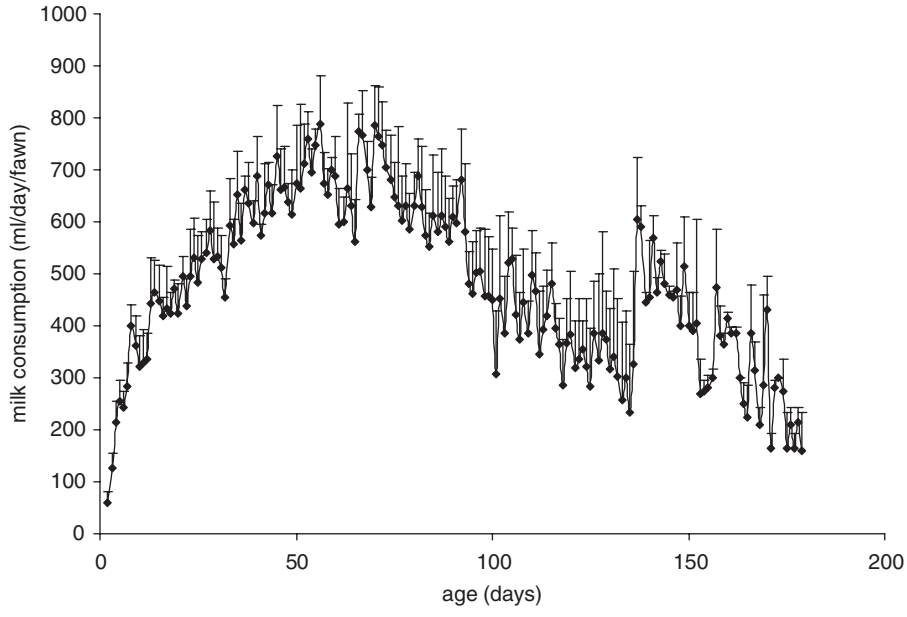

Fig. 1. Daily milk intake of four hand-reared Roe deer *Capreolus capreolus* fawns in Israel (mean+SE).

	FEEDING FREQUENCY (MEALS PER DAY)	
AGE (WEEKS)	MEAN	RANGE
1	8	4–15
2–6	5	3–7
7–14	4	2–7
15–21	3	2–5
22–24	2	1–4

Table 2. Feeding frequency of four hand-reared Roe deer *Capreolus capreolus* fawns in Israel.

up with no assistance. All four fawns were established on the bottle in 8 days. As they became accustomed to the bottle, they drank more at each feed and required less feeds each day, eventually feeding during the daytime only (Table 2). The average milk intake of the four fawns reached a maximum after 2 months (*c.* $0 \cdot 8$ litre day^{-1}, Fig. 1). A second peak, at *c.* 130 days, was a result of deviations in the time of weaning.

The fawns began foraging at the age of 2 weeks and gradually consumed a variety of available plants. Two of our fawns weaned themselves at the age of 4 months by rejecting milk offered on two consecutive days (similar to Wayre, 1967; and R. Lambert unpubl. data), while two others kept drinking milk until November (6 months old). They were gradually weaned by reducing the feeding frequency to once a day until they were not given any more milk.

The daily milk consumption quantities of our hand-reared Roe deer were notably lower than those hand-reared by R. Lambert in Scotland (Lambert, 2002). His hand-reared Roe deer consumed an average of 1 litre day^{-1} of milk, from the age of 2 weeks, and at 2 months they consumed a maximum of $1 \cdot 5$ litres day^{-1}. The milk intake is significantly higher in Scotland even after normalization for initial body mass at 1 week (Fig. 2).

The fawns had very little contact with people besides their keeper and would not accept milk from people they did not know well. In order to ensure that they would accept milk from more than just one keeper, an additional person fed the fawns on a daily

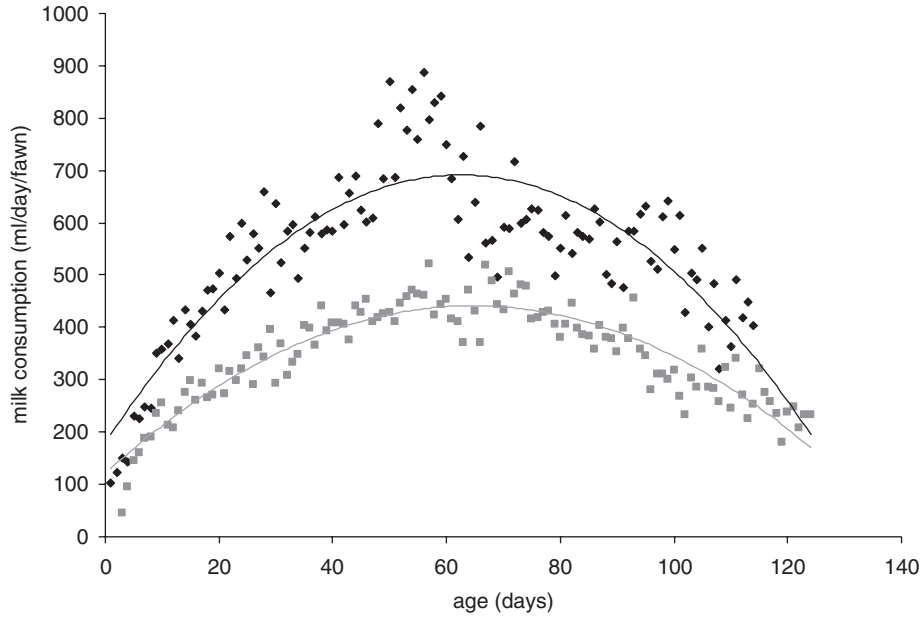

Fig. 2. Daily milk consumption of four hand-reared Roe deer *Capreolus capreolus* fawns in Scotland (black diamonds) and in Israel (grey squares), in 4 months and after normalizing for initial body mass.

basis. Feeding attempts by an unfamiliar person would face active resistance and the fawns would appear to be frightened.

Faeces were soft and yellowish during the first week and they gradually became harder and darker. Within 2–3 weeks, the faeces became dark-brown pellets. They began defaecating independently at the age of 1–2 months. Rectal temperature averaged $38 \cdot 8 \pm 0 \cdot 45\,^{\circ}\mathrm{C}$. The highest recorded temperature was $39 \cdot 6\,^{\circ}\mathrm{C}$, which occurred when a 4 day-old fawn was suffering from a severe case of diarrhoea.

Mean daily growth rate was $108\,\mathrm{g\,day^{-1}}$ ($y = 108 \cdot 46x + 238 \cdot 31$, $R^2 = 0 \cdot 91$, $P \ll 0 \cdot 01$; Fig. 3). The Scottish fawns grew slightly faster ($\mathrm{RGR} = 0 \cdot 6 \pm 0 \cdot 03\,\mathrm{kg\,week^{-1}}$) than the Israeli fawns ($\mathrm{RGR} = 0 \cdot 54 \pm 0 \cdot 02\,\mathrm{kg\,week^{-1}}$), but the difference was not significant (t-test $= 2 \cdot 01$, d.f. $= 6$, $P = 0 \cdot 09$), perhaps owing to the small sample size. Despite the similarity in the fawn's body masses at birth, mother-reared Roe deer grew more than twice as fast as their hand-reared siblings (131 and $54\,\mathrm{g\,day^{-1}}$, respectively, Fig. 4). Nevertheless, the hand-reared Roe deer caught up with the mother-reared fawns (see also Portier *et al*., 2000). At the age of 1 year, the hand-reared Roe deer reached 20 kg and at 2 years they weighed 22–23 kg.

Challenges and benefits of working with hand-reared Roe deer in a natural environment

While taking the fawns out for walks they usually followed the keeper willingly, were extremely enthusiastic and playful and would whine if out of sight of the keeper. As they grew older, these walks became less manageable as the young Roe deer became less responsive to calling. Most problems were encountered in areas of dense vegetation and especially when both fawns were out together. Avoiding such areas and taking each one out separately was helpful during periods when managing the Roe deer was difficult. Although frequently transported by car, starting at $1 \cdot 5$ months old, they did not get into a

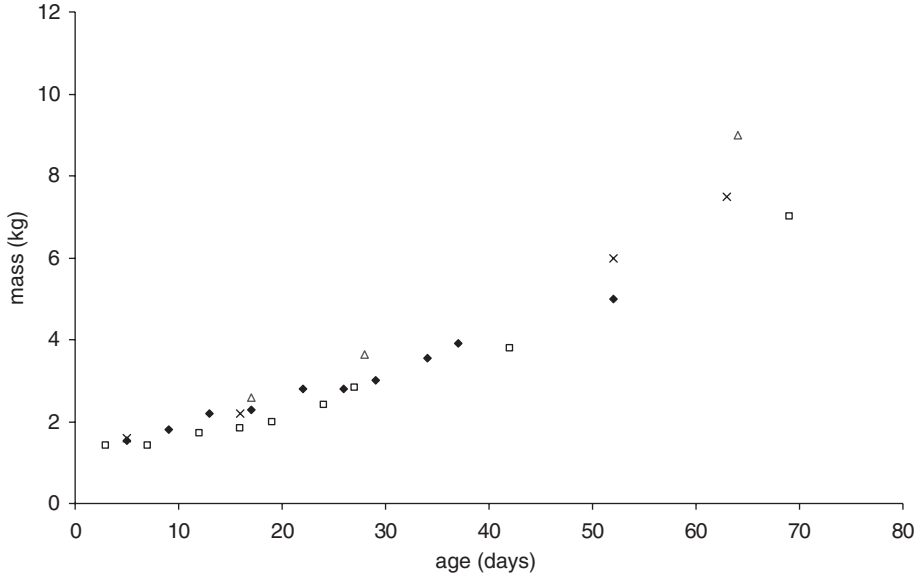

Fig. 3. Growth curve of four hand-reared Roe deer *Capreolus capreolus* fawns (each symbol represents an individual).

car voluntarily and the journeys were usually mildly stressful.

Occasionally, the behaviour of the Roe deer prevented the keeper from pursuing routine work. At times, the Roe deer chose not to appear for days (usually 1–4 days) when called, and locating them was almost impossible in the local dense vegetation. They did not respond to the keeper when it was dark and were less responsive during high daytime temperatures. They also responded negatively to the keeper when they experienced physical restraint or any other stressful event. Even unfamiliar clothing (such as a rain jacket and umbrella) induced such responses occasionally. Negative responses usually lasted several days, and in the most severe case it lasted 2 weeks. When the keeper was absent for long periods of time (over 1 week) it took about a day to return to a normal routine. Negative (aggressive) interactions between the hand-reared Roe deer that did not grow up together were commonplace.

The advantage of the hand-rearing procedure is that a group of Roe deer can be studied under close to free-ranging conditions (Plate 1). The Roe deer will respond to the call of their keeper when mature (over 3 years old), which enables us to locate them in the dense woods and relocate them to other sites. It is possible to observe their natural behaviour with no limit to how close the keeper can be. Unfamiliar people can also observe the Roe deer with ease, although they are

Plate 1. Research with hand-reared Roe deer *Capreolus capreolus* in a natural environment in Israel. *U. Miles*.

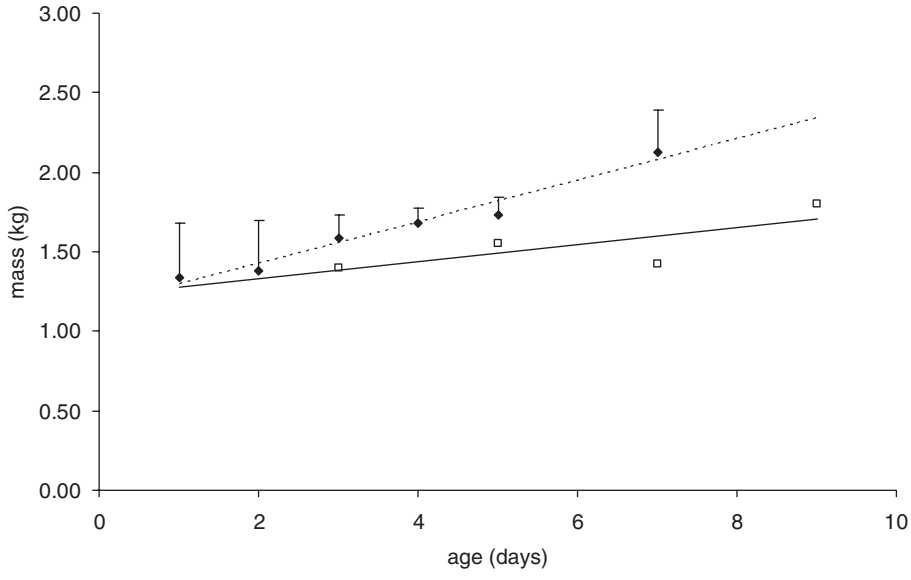

Fig. 4. Growth rate of hand-reared Roe deer *Capreolus capreolus* fawns ($n = 4$, open squares and full line) and their captive mother-reared siblings ($n = 9$, diamonds and dashed line). The hand-reared fawns do not have a deviation mark because not all data points have more than one to two repetitions. A linear line was drawn through the points (hand-reared, $y = 0 \cdot 0535x + 1 \cdot 2215$, $R^2 = 0 \cdot 563$, NS; mother-reared, $y = 0 \cdot 1311x + 1 \cdot 1595$, $R^2 = 0 \cdot 962$, $P < 0 \cdot 01$).

generally wary and will not respond to anyone other than their keeper. Whether it is possible for them to become familiar with other people has not been determined. There is a wide range of activities that can be carried out with the hand-reared deer in a natural environment (Table 3).

DISCUSSION

Hand-rearing process

Roe deer fawns have been hand-reared using a variety of milk substitutes with a varying degree of success. Although in most cases the reported fawns survived, different growth rates (Table 4) and veterinary issues resulted from the use of each substitute. Pinter (1963) used diluted cow's milk to reduce its high lactose content, which might cause diarrhoea. However, because Roe deer milk is naturally more concentrated and contains more fat, protein and minerals than cow's milk (Csapo *et al*., 1987), the resulting milk substitute is deficient in essential nutrients. The only way to prevent malnutrition is to increase the frequency of meals, which often resulted in indigestion and diarrhoea (Wayre, 1967). Based on data of the milk composition of White-tailed deer *Odocoileus virginianus*, Bradley (1971) used a dog-milk substitute for a Roe deer fawn. The fawn survived but abdominal problems, slow growth rate (Table 4), low milk consumption and early weaning were apparent. Csapó *et al*. (1987) found that the milk composition of different deer species, including Roe deer, is not the same, which might explain the difficulties. Another inappropriate choice was a human milk substitute, which resulted in stunted growth (Baugatz *et al*., 1997; Table 4). Drescher-Kaden *et al*. (1972, 1974) experimented with different substitutes: an equal mixture of cow's milk and condensed milk, two different substitutes made to resemble Roe deer milk and a cow's milk substitute. R. Putman (pers. comm.) highly recommended fresh goat's milk instead of any commercial substitute.

ACTIVITY	DEGREE OF DIFFICULTY	COMMENTS
Collecting urine	1	following the deer until they stop to urinate; urine can be collected in a bowl
Collecting fresh faeces	1	similar to urine collection or collected from the ground
Collecting external parasites	1	deer will allow the keeper to clean them manually of parasites
Weighing	1	using palatable food, the deer can be trained to step on a modified sheep scale within 1 week (Plate 2)
Observing natural behaviour	1	keeper follows the deer passively; deer quickly resume their natural behaviour
Moving the deer on foot	1	deer follows keeper when called
Feeding trials	1	deer will eat out of keeper's hand
Collecting blood smears	2	pricking the ear and drawing a drop of blood is possible when the deer are resting and calm
Lifting the deer off the ground	2	even fawns resist this manipulation
Taking the deer out on a walk	1–3	deer usually follow the keeper, although this is unpredictable
Moving the deer by car	2–3	catching and putting the deer into a car is difficult and stressful; deer were blindfolded when being handled; keeper sits next to the deer throughout the journey
Using a leash	2–3	deer resist being restrained and may not tolerate a leash for long, even from a very young age (<1 week of age)
Confining in a cage-like area for veterinary treatments	3	deer will enter a small confined area but locking them in for more than several minutes may cause panic and injury
Injections	3	two (strong) people are required: one to restrain the deer and the other to inject (veterinarian); to avoid negative associations with the keeper after such procedures, the keeper should not participate in this procedure

Table 3. Management activities that can be carried out with adult hand-reared Roe deer *Capreolus capreolus* does based on the current study. The degree of difficulty is on a scale of 1–3: 1, easily applicable; 2, average; 3, most difficult and perhaps inadvisable.

The lower milk intake of our group might be owing to the difference in the milk substitutes. It is also possible that differences in energy expenditure owing to different ambient temperatures may have caused differences in milk consumption.

Roe deer fawns will usually wean themselves by the age of 6 months (Pinter, 1963; Lambert, 2002), but some hand-reared deer may wean as early as 2 months (Bradley, 1971; Drescher-Kaden *et al*., 1972). This variability in the weaning age of hand-reared Roe deer was exemplified in our case.

R. Putman (pers. comm.) found that if more than one person feeds the fawn, it will generalize on other humans and will become very tame, a condition that is not advisable if the deer are to be released into the wild.

Drescher-Kaden *et al*. (1974) reported a low growth rate of nine fawns, fed on different milk substitutes, during a 2 week *Escherichia coli* infection (44 ± 26 g day^{-1}).

Plate 2. A standard sheep scale was modified for Roe deer *Capreolus capreolus*. The modification includes removing the usual cage structure commonly used for sheep and shaping the scale in such a way as to allow the Roe deer to jump off at will. *A. Wallach*.

Lambert (2002) was the only author to report a growth rate that is similar to mother-reared fawns in the wild, which showed a growth rate of 113–155 g day^{-1} (Andersen, Gaillard

MILK SUBSTITUTE	NO. OF FAWNS	GROWTH RATE (G DAY $^{-1}$)	REFERENCES
Sheep (commercial substitute)	4	108	Current study
Sheep (commercial substitute)	2	109	Baugatz *et al*. (1997)
Human (commercial substitute)	2	73	Baugatz *et al*. (1997)
Dog (commercial substitute)	1	~45	Bradley (1971)
Sheep (commercial substitute)	4	~140	R. Lambert (unpubl. data)
Human (commercial substitute)	1	~100	Wayre (1967)
Cow (commercial substitute)	2	75	Drescher-Kaden *et al*. (1972)
Roe deer (hand made)	8	100	Drescher-Kaden *et al*. (1972)
Cow+condensed milk (1:1)	2	97	Drescher-Kaden *et al*. (1972)

Table 4. Growth rate of Roe deer *Capreolus capreolus* fawns during the first 10 weeks.

& San José, 1998). Even though the number of data points obtained in this period is small, it supports the hypothesis that hand-reared deer do grow at a slower rate than mother-reared deer (Pinter, 1963; Birgersson *et al*., 1998; Portier *et al*., 2000). We found that at the age of 1 year, the hand-reared Roe deer reached 20 kg, and at 2 years they weighed 22–23 kg, which is within the range of European populations (Andersen, Gaillard & San José, 1998).

Hand-reared Roe deer in research

When using hand-reared deer to study issues of physiology or nutrition, no biases are usually expected (Holand, 1994; Spalinger *et al*., 1997; Tixier *et al*., 1998; Dehnhard *et al*., 2001; Lambert, 2002). However, despite the obvious benefits of working with hand-reared Roe deer, several potential biases should be taken into consideration. Activity patterns may be affected by the behaviour of the keeper. The tendency of the Roe deer to follow the keeper may present a major bias with regard to habitat selection and movement. The Roe deer might spend longer periods in open fields when the keeper is present. In addition, we have seen our Roe deer use large vehicle paths that a wild deer might avoid. The presence of the keeper can become a source of conflict and excitement among the Roe deer that otherwise would not arise. Some of these biases can be overcome with planned management of the experiment. However, in some cases, hand-reared deer are not appropriate for research, such as certain aspects of behaviour that are affected by the presence of the keeper.

CONCLUSIONS

Hand-rearing is a time-consuming process that requires knowledge of the animal's biology. The methodology for each species will be unique and therefore we encourage publication of detailed hand-rearing protocols. Using a milk substitute that is similar to the milk composition of the hand-reared species is especially important. It is possible to study hand-reared Roe deer in large habitats and to maintain a close relationship with them in their adulthood. Therefore, hand-reared Roe deer are a potentially useful tool in physiological and ecological studies. When setting up a research programme with hand-reared Roe deer, it is advisable to take into consideration the limiting factors and potential biases. As far as we know, this is the first documented case in which hand-rearing was used as a tool for carrying out a feasibility study for a reintroduction programme. This approach might be found useful for other programmes as well.

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PRODUCTS MENTIONED IN THE TEXT

Probiotics: supplemented stomach bacteria (Probiotics, Clarksdale, MO, USA), Primalac Star-Labs/Forage Research, Inc., USA.

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