



Description of box trapping, immobilisation, anaesthesia monitoring and blood chemistry and serology in free-ranging European wildcats (*Felis silvestris*) in Southwest Germany

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Abstract

Specific questions in wildlife research and surveillance require safe and efficient capture, handling and anaesthesia protocols to enable sampling and transmitter placement in free-ranging individuals. For wild felids, various protocols are available, but detailed reports for European wildcats (*Felis silvestris*) are scarce. In particular, tools for anaesthesia monitoring under field conditions and reference values for heart rate, respiratory rate, oxygen saturation and body temperature are missing. In the present study, European wildcats were caught in box traps before being released into catch bags for manual restraint. Inside the bags, ketamine-xylazine anaesthesia was applied via intramuscular injection, adjusted to the animal's body weight. During anaesthesia, samples were taken, and vital variables were monitored continuously. Haematology and blood chemistry parameters were obtained, along with serological markers for antibodies against feline immunodeficiency virus (FIV), feline coronavirus and antigens of feline leukaemia virus (FeLV). In total, 29 wildcats were captured, of which 21 were examined and marked with passive integrated transponders. Twelve wildcats were collared with GPS transmitters. Handling time under anaesthesia averaged 30 min (range 26–35 min). Heart rate ranged between 76 and 170 beats/min and respiratory rate between 20 and 52 breaths/min. Relative arterial oxygen saturation stayed mainly between 93 and 99%, and rectal temperature ranged between 36.2 and 40.2 °C. Further, FeLV antibodies were detected in 2/21 samples. The applied protocol facilitated safe and sufficient examination, sampling and transmitter placement, as well as the establishment of haematological and blood chemical values in free-ranging European wildcats for the first time.

Keywords Telemetry · Animal welfare · Live trap · Field work · Serum chemistry values

Introduction

The European wildcat (*Felis silvestris*) is the most prevalent and widely distributed wild felid species in Europe and classified in the category 'Least Concern' by the International

Union for the Conservation of Nature (IUCN) (Gerngross et al. 2022). It is strictly protected throughout most of its European range and listed in CITES Appendix II and Annex IV of the EU Habitats & Species Directive, as well as in Appendix II of the Bern Convention. In Germany, the European wildcat was historically close to extinction. Populations persisted only in a few areas, such as the low mountain

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ranges of Harz, Eifel and Taunus (Piechocki 1990; Raimer 1988). Whilst hunting had been one of the major threats prior to 1934, nowadays, the European wildcat populations are threatened by road kills (Bastianelli et al. 2021), habitat fragmentation (Klar et al. 2009; McOrist and Kitchener 1996; Stahl and Artois 1994), hybridisation with domestic cats (Germain 2007; Hertwig et al. 2009; Steyer et al. 2015) and viral infections (Steeb 2015; Steeb et al. 2011). However, expansion to former lost regions has also been recognised (Steyer et al. 2016).

Based on the European Council Directive 92/43/EEC (Appendix IV), monitoring of wildcats is required; however, currently, the extent and methods differ among the member states of the European Union. Monitoring methods are mainly based on sightings, camera and live trapping, radio tracking, scat and track surveys, as well as on roadkill documentation and the genetic analysis of hair samples collected by using lure sticks (Hupe and Simon 2007; Steyer et al. 2012). Among the different monitoring methods, live trapping of wildcats and the installation of transmitters for telemetry offer the most detailed insights into the behaviour, spatial distribution, social organisation and physical conditions (e.g. sex, age, size and clinical health) of wildcats. Moreover, live trapping provides the possibility of taking various samples for the genetic analysis and health assessment of individuals (Steyer et al. 2012).

Professional handling during trapping and sampling is necessary to guarantee the welfare, health and survival of the handled individuals. To ensure a safe and accurate sampling procedure and the attachment of tracking devices without disproportionate stress for the animal, anaesthesia is necessary. Anaesthesia may not only help to minimise stress but also the risk of injuries for the captured animal and the involved researchers (Goodman et al. 2013; Michler et al. 2015). However, anaesthesia of free-ranging animals that need to be returned into the wild should always be as short as possible, with a quick induction, and well tolerated, without disproportionate side effects (Rockhill et al. 2011). This requires an anaesthesia that includes, if possible, all of the following properties: a high efficacy, a high therapeutic index, maintenance of the swallowing reflex, no influence on the reproductive or survival rate, rapid metabolism, amnesic effect and safety for the operator (Kreeger and Arnemo 2007). Several protocols for the anaesthesia of wild felids have been published (e.g. European wildcat (Bizzarri et al. 2010; McOrist 1992; Potocnik et al. 2002), Sardinian wildcat (*Felis silvestris lybica*) (Murgia and Murgia 2012), bobcat (*Lynx rufus*) (Rockhill et al. 2011), jaguar (*Panthera onca*) (Deem 2002) and leopard cat (*Prionailurus bengalensis*) (Van der Meer et al. 2022)).

To determinate the health status of the animal, a thorough clinical examination including external examination, palpation, rectal temperature measurement, monitoring of

respiratory and cardiac parameters and auscultation of heart and airways is advisable. Moreover, blood sampling for the analysis of blood chemistry values may provide important information about the animal's health. However, these clinical parameters, as well as haematology and serum chemistry values, have not been recorded in previous studies on free-ranging European wildcats. Therefore, in the absence of species-specific parameters, comparisons need to be drawn to values from the domestic cat (*Felis catus*), although species-specific variations and differences between free-ranging and captive individuals are likely (Marco et al. 2000).

The aim of the present study was to perform clinical examinations, including anaesthesia monitoring, and to record species-specific clinical parameters in free-ranging European wildcats. Trapping, handling and anaesthesia protocols should be optimised to facilitate safe transmitter placement and accurate sampling. Furthermore, haematology and serum chemistry values are determined in free-ranging wildcats from Germany for the first time.

Material and methods

Between January 24 and March 2, 2017, 23 custom-made wooden box traps with the dimensions of 100×30×30 cm were prepared with valerian (*Valeriana officinalis*) to attract wildcats in the 'Soonwald' part of the low mountain forest range 'Hunsrück' in Rhineland-Palatinate (Southwest Germany) (Fig. 1). The 'Soonwald' is a contiguous forest area and consists of two completely forested low mountain ridges, 300 km² in size, with heights up to 660 m above sea level, surrounded by agricultural land (mainly meadows) and small villages. The forest cover is dominated by semi-natural beech (*Fagus sylvatica*) and oak (*Quercus robur*) forests mixed with spruce (*Picea abies*), with long meadow valleys and deeply incised stream valleys covering less than 5% of the area. Over the past 25 years, hurricanes have created large areas of richly structured windthrows and semi-natural young successional forests. At higher elevations, precipitation is 700–900 mm, and the average annual temperature is 7 °C. During the trapping sessions, the night temperatures ranged from –5 to 0 °C. Traps were placed every 500–1000 m at sheltered places in the forest close to forest roads (50–300 m distance to the forest road). Each trap consisted of a flap door at one side and a wire netting (mesh size 20×20 mm) on the other side. Traps were equipped with an electronic trap sensor system 'MinkPolice' (Alert House ApS, Vanlose, Denmark) to notify the researchers of the closure of the trap and to monitor the time the animal stayed inside the trap: a central server alerted via email and a short app-based message when the trap was closed. Immediately after notification, the traps were inspected for the presence of trapped animals to enable the immediate release



Fig. 1 Wooden box traps with electronic trap sensor system

of bycatch (e.g. squirrel, fox and pine marten) or to start the preparation of anaesthesia and the examination of a trapped wildcat. Independent of alerts about trap closure, results of automatic routine function check-ups and status updates on the battery charge of the electronic trap sensors were sent twice daily to ensure appropriate trap function.

Wildcat examination and sampling were performed at the trapping site (Goodman et al. 2013; Michler et al. 2015). For treatment, the wildcats were taken out of the trap into a hessian sack (jute sack). This was done by pulling the opening of the sack over the trap to hold the sack open in front of the trap door and then opening the trap door. Once the cat had left the trap for the apparent security of the dark interior of the sack, the end of the sack was sealed, and the animal was restrained inside the sack. The cat's body mass was measured by using a digital spring balance attached to the sack. Afterwards, it was checked for the presence of an already installed passive integrated micro-transponder (PIT) tag or a GPS collar. If a PIT tag or GPS collar was present, it was released. If not, the anaesthetic dosages were calculated to the body mass and administered by intramuscular injection in the upper lateral leg muscles (*Musculus (M.) gluteus superficialis* or *M. biceps femoris*) after the animal was fixated inside the sack. Anaesthesia was performed using a mixture of 10 mL of ketamine-hydrochloride 10% (Medistar Arzneimittelvertrieb GmbH, Ascheberg, Germany) in combination with 7.5 mL of xylazine 2% (Rompun® 2%, Bayer, Leverkusen, Germany), applying 0.175 mL (= 10 mg/kg ketamine and 1.5 mg/kg xylazine) per kg body weight. The duration between injection and complete immobilisation (no visible head movement) was recorded using a stopwatch. After removal from the sack, the animal was placed in right lateral recumbency on a 6-cm-thick polystyrene board, close to a hot-water bag, and covered with blankets to maintain normal body temperature (normothermia) (Potocnik et al. 2002). The mouth was manually opened, a wine cork was placed between the right-upper and right-lower canines to

keep it open and the tongue was drawn out of the mouth. An ophthalmic ointment was applied to both eyes to prevent drying and injury of the cornea (Corneregel, Bausch & Lomb GmbH, Berlin, Germany) (Biró et al. 2004; Potocnik et al. 2002). Anaesthesia monitoring included the continuous monitoring of heart and lung functions via auscultation to check the heart rate, breathing rate and the occurrence of arrhythmia. Corneal reflexes and rectal body temperature were monitored using a cotton stick and a commercial thermometer, respectively (Fig. 2). Additionally, pulse rate and oxygen saturation were measured constantly at the cat's tongue using a tongue clip (Veterinary Handheld Pulse Oximeter UT100V, Utech Co. Ltd., Chongqing, China) (Fig. 2). A peripheral venous catheter (Vasofix® Braunüle® G24 vs. G22, B. Braun Melsungen AG, Melsungen, Germany) was placed in the cephalic or saphenous vein, respectively, to draw a blood sample and to have a venous catheter in place for immediate intravenous drug administration if required in case of emergency or an anaesthetic complication. In this regard, atropine (0.04 mg/kg body weight IV, atropinsulfat 0.5 mg/mL, B. Braun), adrenalin (0.01–0.02 mg/kg body weight IV, adrenalin 1:1,000, Infectopharm Arzn. u. Consilium GmbH, Heppenheim, Germany), doxapram (0.05–0.2 mg/kg body weight IM, IV, SC, doxapram V 20 mg/mL, Albrecht GmbH, Aulendorf, Germany) and atipamezole (0.05–0.2 mg/kg IM, Antisedan 5 mg/mL, Vetoquinol GmbH, Ismaning, Germany) were ready at hand to be used immediately, as well as endotracheal tubes (inner diameter (ID) 2.0–3.5 mm, Wolfram Droh GmbH, Mainz, Germany) and infant mucus extractors (Medi-King Medical Trading GmbH, Oyten, Germany).

Blood samples were placed immediately in EDTA and serum tubes, stored at 4 °C and transported to a laboratory (Biocontrol Veterinär Labor Partner, Mainz, Germany) for blood chemical and haematological examination. Briefly, the activities of alanine aminotransferase (ALT), aspartate aminotransferase (AST), creatine kinase (CK), gamma



Fig. 2 Monitoring and sampling of wildcats during anaesthesia: measurement of rectal temperature and blood collection (left) and saturation of peripheral oxygen and pulse monitoring (right)

glutamyltransferase (GGT), glutamate dehydrogenase (GLDH), alkaline phosphatase (AP), alpha amylase and lipase and the concentrations of triglycerides, cholesterol, urea, total bilirubin, creatinine, fructosamine, sodium, potassium, calcium, phosphate and chloride were measured using a Cobas C8000 analyser (Roche Diagnostics GmbH, Mannheim, Germany) in serum samples. Likewise, the plasmatic concentrations of total proteins (TP), albumin, globulin and albumin-globulin ratio (A/G) were analysed. Serum protein electrophoresis was performed to determine alpha 1, alpha 2, beta 1, beta 2 and gamma globulin fractions using a MiniCap (Sebia, Fulda, Germany). Haematological examination included total and differential (neutrophils, lymphocytes, monocytes, eosinophils, basophils, large unstained cells (LUC)) leukocyte counts, erythrocyte count, haemoglobin concentration, haematocrit, mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC) and thrombocyte count and was performed in EDTA blood samples using an ADVIA 2120 with the multispecies software package (Siemens Healthcare GmbH, Eschborn, Germany). According to the Standard Operating Procedures of the Biocontrol laboratory manual, leukocyte differential counts were performed when there were suspicions for imprecise automated differentials or, in certain case, haematological aberrations (e.g. marked neutrophilia or eosinophilia). The haematological analysis of feline blood in the laboratory has been accredited by DIN ISO17025 standards. Additionally, serum samples were examined for antibodies against feline immunodeficiency virus (FIV) and antigens against feline leukaemia virus (FeLV), using qualitative ELISAs (MegaCor Diagnostik GmbH, Lindau (Bodensee), Germany). Antibodies against feline coronavirus were analysed using an

in-house IFAT, accredited to DIN ISO 17025 standards, at Biocontrol Veterinär Labor Partner, Mainz, Germany.

Oral swabs (saliva samples) were taken and forwarded to the Conservation Genetics Group of the Senckenberg Research Institute and Natural History Museum in Frankfurt, Germany, for molecular examination using mtDNA and microsatellites to confirm that the individual is a European wildcat and not a domestic cat or a hybrid (methods see Steyer et al. 2016).

Total body length (including the head) (cm), tail length (cm), ear length (cm), neck circumference (cm), thorax circumference (cm), scapula height (cm), hind foot length (cm), front paw width (mm), front paw diameter (mm) and canine length of the upper and the lower jaw of both sides (mm) were measured according to standard procedures (Müller 2005, 2011; Müller and König 2015). Overall body condition and subcutaneous fat deposits were assessed visually and by palpation. Finally, a sterile PIT tag (AL-Vet Mini ISO transponder, Albrecht GmbH, Aulendorf, Germany) was placed subcutaneously at the left side of the neck, and a GPS collar (70 g, e-obs digital telemetry, e-obs GmbH, Grünwald, Germany) was placed around the animal's neck.

After the completion of measuring and sampling, the total handling time of the cats was documented prior to injecting 0.05–0.2 mg/kg atipamezole IM (Antisedan 5 mg/mL) as reversal and placing the cat inside the box traps for wakeup. Prior to opening the trap for release, complete recovery from anaesthesia and restoring of coordination were checked from a distance by looking through the wire netting. Only when the wildcats were fully awake, bright, alert, responsive and able to stand and walk inside the trap, they were released. All procedures were performed in accordance with European

animal welfare law and permitted by the animal welfare authority (permission no.: 23177–07/G 16–20-092 Landesuntersuchungsamt Rheinland-Pfalz).

Statistical analyses including the calculation of the median (x_{med}), 1st (Q_1) and 3rd (Q_3) quartile, 2.5% and 97.5% percentiles as well as arithmetic mean (\bar{x}) and standard deviation (SD) of body weight, body measurements and blood parameters, besides graphical description of anaesthesia monitoring parameters (heart rate, breath rate, relative arterial oxygen saturation, body temperature), were performed using the programmes Excel (Microsoft® Excel® 2013, version 15.0.4963.1002, Microsoft Corporation, Redmond, Washington, USA) and R (R Core Team, version 4.2.2., Vienna, Austria; <https://www.R-project.org>).

Results

In total, 29 wildcats (23 males, 6 females; 28 adult, 1 sub-adult) were captured between January 24 and March 2, 2017 (the total trapping period covered 37 days). Seven males were captured twice (resulting in 36 successful catches of wildcats during the trapping period) and were identified by reading of the PIT tags before injecting anaesthesia medication. Hence, they were released after weighing, and a second immobilisation was avoided. Most of these wildcats (26/29) entered the trap during nighttime, in particular between 6:30 PM and 5:35 AM, and only 3/29 individuals were caught in the late morning (9:03 AM) or in the afternoon (4:09 PM and 4:40 PM). The average time ($\bar{x} \pm \text{SD}$) animals stayed inside the traps was 137 ± 101.4 min. Genetic analysis of saliva samples confirmed that all examined animals ($n = 29$) were European wildcats.

Body measurements were larger in males than in females; however, some individuals were within the ranges of the other sex (Table 1). Body condition and state of nutrition were good in 26/29, moderate in 1/29 and poor in 2/29 of the wildcats. Acute and thus potentially trap-associated injuries were recorded in 11/29 individuals and consisted mainly of superficial foot and talon injuries, seldom in injuries at the rhinarium.

Total handling time under anaesthesia varied from 26 to 35 min (average 30 min). Ketamine-xylazine combination provided a safe and sufficient anaesthesia during handling, measuring and sampling. Only in two male wildcats (M9, M12), a second injection of one third of the initial dose of the anaesthetic combination needed to be given after 14 and 20 min past initial injection, respectively, as blink reflexes had returned in these two wildcats at that time. Intravenous catheter placement in the cephalic or saphenous vein at the beginning of the anaesthesia was well suited to draw blood or to administer drugs such as atropine, doxapram or Ringer's solution.

During anaesthesia, the heart rate ranged from 76 to 170 beats/min (Supplemental Material 1). It dropped mildly

during the first minutes after induction, remained constant at 120–150 beats/min in most animals and finally dropped in four animals at the end of anaesthesia (M4, M13, M17, M21) (Supplemental Material 1).

In contrast, the heart rate finally increased in three animals (F4, F5, F6), but two of them (F5, F6) received intravenous injections of atropine in reaction to mild arrhythmia upon its detection during auscultation. The application of atropine resulted in a stabilisation in terms of an increased but rhythmic heartbeat and a strong peripheral pulse. The same applies to five other wildcats (M6, M16, M14, M16, M18, M19), which received atropine likewise.

Respiratory rate ranged between 20 and 52 breaths/min but stayed between 25 and 40 breaths/min in most animals during anaesthesia (Supplemental Material 2). The maximum of 52 breaths/min was observed in one female (F4) in the first minutes of anaesthesia only and might have been influenced by mild panting. The minimum of 20 breaths/min was recorded in four wildcats (F5, M14, M16, M21) and remained in two wildcats (M14, M21) at this value for 20 min (Supplemental Material 2). One wildcat (F14) had arrhythmic respiratory patterns 19 min after induction and thus received 0.3 mL atropine and 0.2 mL doxapram intravenously.

Relative arterial oxygen saturation varied between 89 and 100% but mainly ranged from 93 to 99% (Supplemental Material 3). The minimum of 89% was recorded in one wildcat (F5) and improved few minutes after to 94% and finally to 96%. This female received 80 mL of Ringer's solution and 0.28 mL of atropine intravenously in reaction to the low oxygen saturation.

Rectal temperature ranged between 36.2 and 40.2 °C but mainly stayed between 37 and 39 °C in most wildcats. In all wildcats, it decreased during the course of anaesthesia. In four wildcats (M9, M11, M18, M23), rectal temperature was equal or above 39 °C, and in three of them (M9, M11, M23), it dropped only slowly, despite the removal of blankets and hot-water bags. The body temperature of one wildcat (M8) dropped to 36.2 °C at the end of anaesthesia, whereas all other wildcats maintained temperatures above 36.5 to 37.0 °C. The average body temperature drop was between 0.5 and 1.1 °C.

No wildcats died during trapping and handling, and all survived for more than 6 months after release. All 29 immobilised wildcats were identified with a PIT tag, and 12 of them were additionally equipped with a GPS collar. Upon release, all collared wildcats were bright, alert and responsive and able to stand and walk without any visible impairment. Likewise, altered or suspicious behaviour was not observed during a period of at least 6 months. Two non-collared males were identified by their PIT tags after being found dead on roads (M14 in October 2017, 8 months after release; M12 at the end of March 2018, 14 months after release).

The results of tests for antibodies against FIV and feline coronavirus were weak positive in samples from one wildcat

Table 1 Biological scales and measures of 29 European wildcats

	Body weight (g)	Total body length (cm)	Tail length (cm)	Ear length (cm)	Neck circumference (cm)	Thorax circumference (cm)	Scapula height (cm)	Hint foot length (cm)	Front paw width (mm)	Front paw diameter (Ø mm)	Canine length upper jaw left (mm)	Canine length upper jaw right (mm)	Canine length lower jaw left (mm)	Canine length lower jaw right (mm)
All wildcat (n=29)														
Mean	4243	91.50	29.55	5.52	18.41	31.06	35.31	13.18	20.62	37.10	11.83	12.00	10.40	10.15
SD	571	5.45	4.58	0.15	1.46	1.51	2.42	0.94	1.29	3.64	1.67	1.09	1.14	1.27
Min	3230	77.00	7.00	5.20	15.00	29.00	28.00	12.00	17.50	30.00	7.00	10.00	8.00	6.00
Max	5550	101.00	33.00	5.80	22.00	34.00	39.00	17.30	24.00	48.00	14.50	14.50	13.50	12.00
Median	4150	92.00	30.00	5.53	18.50	31.00	35.00	13.10	20.50	37.00	12.00	11.75	10.20	10.50
1 st quartile	3990	89.25	29.00	5.50	18.00	30.00	33.50	12.85	20.00	35.00	11.00	11.00	10.00	9.55
3 rd quartile	4490	95.75	32.00	5.60	19.00	32.25	37.00	13.50	21.00	39.00	13.00	13.00	11.00	11.00
Males only (n=23)														
Mean	4412	91.50	29.55	5.52	18.41	31.06	35.31	13.18	20.62	37.10	11.83	12.00	10.40	10.15
SD	510	5.45	4.58	0.15	1.46	1.51	2.42	0.94	1.29	3.64	1.67	1.09	1.14	1.27
Min	3500	77.00	7.00	5.20	15.00	29.00	28.00	12.00	17.50	30.00	7.00	10.00	8.00	6.00
Max	5550	101.00	33.00	5.80	22.00	34.00	39.00	17.30	24.00	48.00	14.50	14.50	13.50	12.00
Median	4225	92.00	30.00	5.53	18.50	31.00	35.00	13.10	20.50	37.00	12.00	11.75	10.20	10.50
1 st quartile	4090	89.25	29.00	5.50	18.00	30.00	33.50	12.85	20.00	35.00	11.00	11.00	10.00	9.55
3 rd quartile	4600	95.75	32.00	5.60	19.00	32.25	37.00	13.50	21.00	39.00	13.00	13.00	11.00	11.00
Females only (n=6)														
Mean	3595	83.50	28.17	5.34	16.50	30.50	32.00	12.30	19.63	35.00	10.28	10.92	9.20	9.17
SD	229	4.31	1.07	0.19	0.96	1.50	1.91	0.42	1.29	1.87	1.20	0.45	0.93	0.84
Min	3230	77.00	27.00	5.20	15.00	29.00	28.00	12.00	17.50	32.00	8.00	10.00	8.00	8.00
Max	3995	91.00	30.00	5.70	18.00	33.00	34.00	13.20	21.00	37.00	11.50	11.50	10.20	10.00
Median	3580	83.50	28.00	5.23	16.50	30.00	32.50	12.15	20.00	35.50	10.75	11.00	9.50	9.55
1 st quartile	3425	80.00	27.00	5.20	15.75	29.25	31.00	12.00	18.13	32.75	9.13	10.68	8.00	8.00
3 rd quartile	3770	86.50	29.25	5.55	17.25	32.25	33.25	12.53	20.75	36.75	11.28	11.20	10.05	9.93

(M2). Antigen detection of FeLV was positive in two wildcats (M20, M22). The blood chemical and haematological results are summarised in Tables 2 and 3.

Discussion

The trapping of wildcats was easily feasible and in accordance with animal welfare law, using valerian-baited box traps. Therefore, the usage of live animals as bait was not necessary, as described elsewhere (Bizzarri et al. 2010). This corresponds to previous studies using valerian as attractive and non-invasive bait to lure wildcats (e.g. valerian lure sticks for genetic wildcat monitoring) (Steyer et al. 2012; Velli et al. 2015). The capture success for wildcats in the winter of 2017 was surprisingly high. In our study, 36 captures of 29 individual wildcats occurred in 37 days and 411 trap nights, which equals to one wildcat capture per 11.4 trap nights. The trapping results were similar to those reported by Campbell and Griffith (2015) (one wildcat capture per 11.1 trap nights) but better than those of most previous studies (one wildcat per 333 trap days (Ragni 2005), one wildcat per 209.5 trap days (Bizzarri et al. 2010), one wildcat per 57.7 trap days (Potocnik et al. 2002) and one wildcat per 52.9 trap days (Dötterer and Bernhart 1996)). In accordance to a study in Slovenia, the use of box traps seems to be a well-suited and effective method to trap free-ranging European wildcats (Potocnik et al. 2002). This can be underlined by the animal welfare aspects as in the present study that only acute, mild trap-associated injuries, such as superficial foot and talon injuries, were recorded in 37.9% of the wildcats. Therefore, trapping-associated injuries were lower compared to those of previous studies reporting lacerations and abrasions in the frontal and orbital regions, caused by bumping into the wire-netting doors of wired cage traps (Potocnik et al. 2002). However, optimisation of the used box traps might be attempted by the installation of a locking trigger mechanism and the complete closure of traps to prevent scratching or biting (Ziegler et al. 2018). The sex ratio of the trapped wildcats in the present study was biased to males (5 males: 1 female), agreeing with previous reports (Bizzarri et al. 2010; Potocnik et al. 2002; Van der Meer et al. 2022). This may primarily have been caused by the high male mobility during the mating season and may additionally be a result of constitutive sex-biased differences in behaviour, as reported in several wildcat species (Kvam 1991). In average, the wildcats stayed inside the traps for a shorter period as compared to previous studies (Bizzarri et al. 2010), which might be explained by the usage of alarming techniques immediately alerting of the closing of the trap (Bizzarri et al. 2010). In line with other authors (Will et al. 2010; Ziegler et al. 2018), the use of a trap alarm is recommended from an animal welfare point of view.

Average and mean body weights, body condition and body measurements of wildcats were in accordance to previous studies on road-killed wildcats in Germany (Müller 2005, 2011; Müller and König 2015). However, ear length in male wildcats was below previously published measurements (ear length, 6.0–7.0 cm; mean, 6.46 cm; thorax circumference, 26.0–48.0 cm; mean, 32.33 cm) and thorax circumference above previous measurements (22.5–34.5 cm; mean, 28.64 cm), which may be the result of slightly different methods of measuring the length and circumference. However, the differences in thorax circumference could have been caused by the comparison of alive and dead wildcats, with higher measurements in living animals (Müller and König 2016). In the present study, 28/29 wildcats were identified as adult individuals (> 2 years old) by measurement of hind foot length and status and the wear of canine teeth. One male (M3) was probably in the second year of life. General differences in weight and body measurements between young (first year) and older individuals, as described in previous reports, could not be confirmed as a more detailed age estimation *in vivo* was not possible (Müller 2005, 2011; Müller and König 2015). In the present study, the female wildcats weighed 3.2–4.0 kg and the males 4.0–5.6 kg. The recaptures detected individual weight changes within a few weeks, which are not unusual during the mating season. Whilst one non-collared male lost 300 g within 3 weeks, another male increased in weight (100 g) within 1 week. Nevertheless, all caught individuals were regarded as normally sized and developed based on body weights and measurements.

Clinical examination revealed no signs of diseases or severe injuries, except for two individuals, which showed a poor body condition and acute, mild, trap-associated injuries. However, as a decrease in body weight is not unusual during the mating season in winter, all wildcats included in the present study were regarded as healthy and suitable for anaesthesia. The anaesthetic combination of ketamine and xylazine and the handling protocol worked out without anaesthetic accidents or early wakeup events, thus improving the protocol in a previous study in Slovenia using medetomidine instead of xylazine (Potocnik et al. 2002). However, a detailed comparison is limited as in the latter study, and no detailed information about the dosage of ketamine was provided. Thus, a difference in ketamine dosage might have been responsible for the observed differences, besides the use of xylazine. Drug administration via a blowpipe seemed disadvantageous compared to direct syringe injection through the Hessian sack due to the risk of ricocheting of the darts, muscle trauma, failed drug injection, false estimation of body weight and, therefore, false dosage of anaesthetic drugs (see also Michler et al. 2015 with similar experiences in racoons). Out of similar reasons, the authors of the previous study stopped using the blowpipe in racoons

Table 2 Results of blood chemistry and protein electrophoresis of 21 European wildcats

		All wildcats (<i>n</i> = 21)								
		Range					Quartile		Percentile	
		Min	Max	Mean	SD	Median	1st	3rd	2.5%	97.5%
Sodium (ISE)	mmol/L	151.0	161.0	156.2	2.6	156	155	157	152.0	161.0
Potassium (ISE)	mmol/L	3.9	5.0	4.3	0.3	4.3	4.1	4.4	4.0	4.9
Calcium	mmol/L	2.2	2.7	2.5	0.1	2.5	2.4	2.6	2.4	2.7
Ianorg. phosphate	mmol/L	1.2	2.2	1.6	0.2	1.7	1.5	1.7	1.3	2.0
Chloride (ISE)	mmol/L	100.0	113.0	108.1	2.9	109.0	106.3	110.0	105.0	112.5
CK (IFCC)	U/L	371.0	3600.0	1052.1	799.0	875.5	489.8	1115.3	380.9	3030.0
ALT	U/L	81.0	260.0	139.6	51.3	114.5	107.0	166.0	101.5	251.9
AST	U/L	44.0	199.0	96.1	39.0	83.0	71.5	122.3	58.9	188.6
GGT	U/L	3.0	3.0	3.0	0.0	3.0	3.0	3.0	3.0	3.0
AP	U/L	5.0	46.0	23.4	9.2	23.5	18.0	29.5	14.0	39.8
GLDH	U/L	2.1	15.5	5.8	3.6	4.6	3.1	7.9	2.3	14.5
Alpha-amylase	U/L	520.0	975.0	679.3	135.6	654.5	559.5	748.3	521.8	968.4
Lipase	U/L	10.0	17.0	13.0	2.2	12.5	11.0	15.0	10.0	17.0
Bilirubin, total	µmol/L	1.7	1.7	1.7	0.0	1.7	1.7	1.7	1.7	1.7
Creatinine (enzym.)	µmol/L	53.0	88.4	69.0	9.7	70.7	61.9	75.1	52.8	88.0
Urea	mmol/L	20.7	53.4	35.3	9.0	34.5	28.3	42.2	23.6	51.1
Protein, total (TP)	g/L	64.0	90.0	72.6	6.3	72.0	67.5	74.5	67.0	88.5
Albumin	g/L	32.9	44.2	37.1	3.1	37.4	33.9	38.8	33.4	43.3
Globulin, total	g/L	26.0	52.9	35.4	6.9	314.6	30.4	38.9	28.6	52.9
A/G ratio		0.6	1.6	1.1	0.2	1.0	0.9	1.2	0.8	1.6
		Protein electrophoresis (PE)								
Albumin (PE)	g/L	25.6	52.2	35.7	0.3	35.4	30.1	39.6	28.3	51.2
Alpha-1-globulin	g/L	2.6	7.2	4.4	0.1	4.6	3.4	5.0	3.4	6.9
Alpha-2-globulin	g/L	7.6	19.6	11.0	0.1	10.3	9.1	12.4	8.9	18.1
Beta-1-globulin	g/L	0.3	3.2	1.7	0.0	1.9	1.4	2.2	1.2	3.1
Beta-2-globulin	g/L	0.3	10.3	6.0	0.2	6.1	4.5	8.1	4.2	10.1
Gamma-globulin	g/L	7.0	25.2	13.4	0.3	13.7	10.0	15.2	9.0	24.1
Albumin (PE)	%	40.0	58.0	49.1	5.4	49.2	44.6	53.2	42.2	57.9
Alpha-1-globulin	%	4.1	8.0	6.1	1.0	6.4	5.0	6.7	5.0	7.8
Alpha-2-globulin	%	11.8	21.8	15.2	2.4	14.3	13.4	16.7	13.3	20.5
Beta-1-globulin	%	0.5	3.6	2.4	0.7	2.6	2.1	2.9	1.8	3.5
Beta-2-globulin	%	0.5	11.4	8.3	2.6	8.4	6.7	10.8	6.3	11.4
Gamma-globulin	%	10.9	28.0	18.5	4.3	19	14.8	20.4	13.4	27.2
A/G-ratio (PE)		0.7	1.4	1.0	0.2	1.0	0.8	1.1	0.7	1.4
Triglycerides	mmol/L	0.2	0.9	0.4	0.2	0.3	0.3	0.4	0.3	0.9
Cholesterol, total	mmol/L	3.2	5.4	4.4	0.7	4.4	3.8	5.1	3.2	5.3
Fructosamine	µmol/L	315.0	470.0	381.3	36.8	384.5	349.8	409.3	337.8	450.5
		Female wildcats (<i>n</i> = 4)								
		Range					Quartile		Percentile	
		Min	Max	Mean	SD	Median	1st	3rd	2.5%	97.5%
Sodium (ISE)	mmol/L	151.0	156.0	153.5	2.1	153.5	151.3	155.8	151.3	159.9
Potassium (ISE)	mmol/L	4.2	4.6	4.4	0.2	4.4	4.2	4.6	4.2	5.0
Calcium	mmol/L	2.4	2.6	2.5	0.1	2.5	2.4	2.5	2.4	2.7
Ianorg. phosphate	mmol/L	1.4	1.6	1.5	0.1	1.6	1.5	1.6	1.5	2.3
Chloride (ISE)	mmol/L	107.0	111.0	109.3	1.5	109.5	107.5	110.8	107.6	113.0

Table 2 (continued)

		Female wildcats (n = 4)								
		Range					Quartile		Percentile	
		Min	Max	Mean	SD	Median	1st	3rd	2.5%	97.5%
CK (IFCC)	U/L	751.0	3600.0	1872.8	1145	1570.0	795.8	3252.5	804.7	2820.0
ALT	U/L	108.0	171.0	126.0	26.2	112.5	108.3	157.3	108.3	260.0
AST	U/L	74.0	177.0	116.3	43.9	107.0	74.3	167.5	74.3	170.2
GGT	U/L	3.0	3.0	3.0	0.0	3.0	3.0	3.0	3.0	3.0
AP	U/L	22.0	33.0	27.5	4.6	27.5	22.5	32.5	22.6	46.0
GLDH	U/L	3.9	15.5	9.3	5.2	8.9	4.0	15.0	4.0	12.9
Alpha-amylase	U/L	647.0	975.0	751	134.1	691	647.3	914.8	647.3	969.8
Lipase	U/L	10.0	15.0	11.8	2.1	11.0	10.0	14.3	10.0	16.3
Bilirubin, total	µmol/L	1.7	1.7	1.7	0.0	1.7	1.7	1.7	1.7	1.7
Creatinine (enzym.)	µmol/L	53.0	70.7	66.3	8.0	70.7	57.5	70.7	61.6	88.0
Urea	mmol/L	20.7	29.6	26.2	3.4	27.2	22.0	29.3	22.3	51.7
Protein, total (TP)	g/L	67.0	90.0	79.8	9.3	81.0	69.0	89.3	69.4	85.1
Albumin	g/L	34.0	40.2	37.5	2.3	37.9	34.9	39.8	35.0	43.5
Globulin, total	g/L	27.2	52.9	42.3	11.0	44.5	29.5	52.9	29.9	47.9
A/G ratio		0.6	1.5	1.0	0.3	0.9	0.7	1.4	0.7	1.6
		Protein electrophoresis (PE)								
Albumin (PE)	g/L	26.8	51.4	37.5	0.6	36.77	28	49.1	28.2	49.4
Alpha-1-globulin	g/L	3.4	4.9	4.2	0.02	4.2	3.5	4.8	3.5	6.8
Alpha-2-globulin	g/L	8.8	12.4	10.7	0.02	10.9	9.1	12.2	9.2	17.5
Beta-1-globulin	g/L	1.5	2.8	2.0	0.04	1.9	1.5	2.7	1.5	2.8
Beta-2-globulin	g/L	4.5	10.2	7.7	0.2	8.2	5.0	10.1	5.1	9.7
Gamma-globulin	g/L	10.0	25.2	17.9	0.5	18.9	11.3	24.6	11.5	22.0
Albumin (PE)	%	40.0	57.1	47.0	6.7	45.4	40.5	55.0	40.6	58.0
Alpha-1-globulin	%	5.0	5.4	5.2	0.2	5.2	5.0	5.4	5.0	8.0
Alpha-2-globulin	%	13.2	13.8	13.4	0.2	13.4	13.2	13.7	13.2	20.6
Beta-1-globulin	%	2.2	3.1	2.5	0.4	2.4	2.2	3.0	2.2	3.3
Beta-2-globulin	%	6.7	11.3	9.6	1.9	10.1	7.3	11.3	7.4	11.4
Gamma-globulin	%	14.9	28.0	22.4	5.1	23.3	16.3	27.5	16.6	25.8
A/G-ratio (PE)		0.7	1.3	0.9	0.2	0.8	0.7	1.2	0.7	1.4
Triglycerides	mmol/L	0.3	0.5	0.3	0.1	0.3	0.3	0.4	0.3	0.7
Cholesterol, total	mmol/L	3.2	3.8	3.5	0.3	3.5	3.2	3.8	3.2	5.3
Fructosamine	µmol/L	327.0	393.0	363.5	23.9	367.0	335.8	387.8	337.5	450.1
		Male wildcats (n = 17)								
		Range					Quartile		Percentile	
		Min	Max	Mean	SD	Median	1st	3rd	2.5%	97.5%
Sodium (ISE)	mmol/L	152.0	161	156.8	2.3	156.5	156	157.8	154.5	161
Potassium (ISE)	mmol/L	3.9	5.0	4.3	0.3	4.3	4.0	4.4	4.0	4.9
Calcium	mmol/L	2.2	2.7	2.5	0.1	2.5	2.4	2.6	2.4	2.7
Ianorg. phosphate	mmol/L	1.2	2.2	1.7	0.2	1.7	1.6	1.7	1.3	2.1
Chloride (ISE)	mmol/L	100.0	1133.0	107.8	3.1	108.5	105.3	109.8	105.0	112.6
CK (IFCC)	U/L	371	2400.0	846.9	509.6	806.0	464	950.8	376.5	2070.0
ALT	U/L	81.0	260.0	142.9	55.4	115.5	105.5	179.5	99.5	253.6
AST	U/L	44.0	199.0	91.1	36.0	83.0	68.8	108.0	58.5	172.4
GGT	U/L	3.0	3.0	3.0	0.0	3.0	3.0	3.0	3.0	3.0
AP	U/L	5.0	46.0	22.4	9.7	22.5	18.0	27.8	10.0	40.8

Table 2 (continued)

		Male wildcats (<i>n</i> = 17)								
		Range					Quartile		Percentile	
		Min	Max	Mean	SD	Median	1st	3rd	2.5%	97.5%
GLDH	U/L	2.1	9.8	4.9	2.4	4.6	3.0	7.6	2.2	9.4
Alpha-amylase	U/L	520	961.0	661.3	129.9	645	538.3	741.5	521	940.4
Lipase	U/L	10.0	17.0	13.3	2.1	13.0	11.3	15.0	11.0	17.0
Bilirubin, total	µmol/L	1.7	1.7	1.7	0.0	1.7	1.7	1.7	1.7	1.7
Creatinine (enzym.)	µmol/L	53.0	88.4	69.0	9.7	70.7	61.9	79.6	61.6	88.0
Urea	mmol/L	21.7	53.4	37.4	8.5	38.1	32.0	45.0	26.4	51.6
Protein, total (TP)	g/L	64.0	77.0	70.9	3.7	72.0	67.5	73.5	65.8	76.6
Albumin	g/L	32.9	44.2	37.0	3.2	37.3	33.6	38.7	33.3	43.4
Globulin, total	g/L	26.0	39.6	33.8	4.0	33.5	30.4	37.9	29.3	39.6
A/G ratio		0.9	1.6	1.1	0.2	1.0	1.0	1.2	0.9	1.5
		Protein electrophoresis (PE)								
Albumin (PE)	g/L	27.1	44.7	35.2	0.2	36.1	30.5	39.1	28.8	44.4
Alpha-1-globulin	g/L	2.6	6.2	4.5	0.04	4.8	3.6	5.0	3.3	6.1
Alpha-2-globulin	g/L	7.6	16.8	11.1	0.1	10.7	9.3	13	8.8	15.9
Beta-1-globulin	g/L	0.3	2.8	1.7	0.03	1.9	1.3	2.1	1.2	2.7
Beta-2-globulin	g/L	0.3	8.8	5.6	0.1	5.8	4.5	7.5	4.2	8.6
Gamma-globulin	g/L	7.0	17.1	12.3	0.1	13.4	9.7	14.7	8.5	16.6
Albumin (PE)	%	42.3	58.0	49.7	4.8	50.1	45.2	53.2	43.8	57.9
Alpha-1-globulin	%	4.1	8.0	6.3	1.0	6.7	5.3	6.8	5.0	7.9
Alpha-2-globulin	%	11.8	21.8	15.7	2.6	14.9	13.8	17.7	13.4	20.8
Beta-1-globulin	%	0.5	3.6	2.4	0.8	2.7	1.9	2.9	1.8	3.5
Beta-2-globulin	%	0.5	11.4	7.9	2.7	8.0	6.6	10.2	6.3	11.2
Gamma-globulin	%	10.9	22.2	17.4	3.3	18.6	14.4	20.0	12.9	21.6
A/G-ratio (PE)		0.7	1.4	1.0	0.2	1.0	0.8	1.1	0.8	1.4
Triglycerides	mmol/L	0.2	0.9	0.4	0.2	0.4	0.3	0.4	0.3	0.9
Cholesterol, total	mmol/L	3.2	5.4	4.6	0.6	4.8	4.0	5.1	3.8	5.3
Fructosamine	µmol/L	315.0	470.0	385.8	38.0	386.5	349.8	415.3	342.5	454.6

Enzymatic colorimetric tests were used for clinical chemistry analyses, except for sodium (Na), potassium (K) and chloride (Cl), which were analysed using ISE (ion selective electrodes). Serum electrophoresis was performed using capillary zone electrophoresis

lanorg. phosphate inorganic phosphate, *IFCC* International Federation of Clinical Chemistry and Laboratory Medicine, *ALT* alanine aminotransferase, *AST* aspartate aminotransferase, *GGT* gamma glutamyltransferase, *AP* alkaline phosphatase, *GLDH* glutamate dehydrogenase, *CK* creatine kinase, *enzym.* enzymatic, *TP* total plasma protein concentration, *A/G ratio* albumin-globulin ratio, *PE* protein electrophoresis

likewise and resorted to restraining individuals in a crush cage (Michler et al. 2015). Drug overdosing and stressful situations were absent in the present study, as reported previously (Potocnik et al. 2002). As detailed data about body temperature, breath and heart rate, along with oxygen saturation, are missing in previous reports in wildcats, a detailed comparison is not possible retrospectively. However, similar results and stable vital parameters (median heart rate of 129 beats/min, respiratory rate of 25 breaths/min, rectal temperature of 38 °C and SpO₂ of 93%) have been reported in bobcats, suggesting that the combination of ketamine and xylazine is a good and safe anaesthetic combination (Rockhill et al. 2011). Moreover, the results in wildcats in this study

agree with recommendations and reference ranges for vital parameters in domestic cats during anaesthesia (Erhardt and Kölle 2004). Onsite handling was useful to reduce the mean handling time, which was considerably higher in previous studies due to a transport time of more than 30 min (Bizzarri et al. 2010). Therefore, the usage of mobile equipment to avoid the transport of animals seems beneficial in zoo and conservation projects (Goodman et al. 2013).

In the present study, the average body temperature drop during anaesthesia was between 0.5 and 1.1 °C, despite outdoor temperatures of approximately -5 to 0 °C. Thus, for the maintenance of body temperature during low temperatures in winter months, the use of an isolating bolster, external heat

Table 3 Haematological results for 21 European wildcats

		All (n = 21)								
		Range					Quartile		Percentile	
		Min	Max	Mean	SD	Median	1st	3rd	2.5%	97.5%
Leukocytes	× 10 ⁹ /L	6.0	20.5	11.1	3.7	10.2	8.5	12.5	8.1	10.2
Erythrocytes	× 10 ¹² /L	6.1	10.3	8.9	0.9	8.7	8.4	9.6	11.5	14.5
Haemoglobin	g/L	99.0	147.0	126.0	12.0	128.0	119.0	134	4.0	5.0
Haematocrit	L/L	0.3	0.5	0.4	0.0	0.4	0.4	0.4	44.0	50.8
MCV	fl	41.0	53.0	45.9	2.4	45.0	45.0	48.0	13.8	15.6
MCH	pg	13.0	16.0	14.3	0.7	14.0	14.0	15.0	30.0	33.0
MCHC	g/L	300.0	330.0	313.0	11.0	310.0	300.0	320.0	2712.0	5941.0
Thrombocytes	× 10 ⁹ /L	236.0	608.0	376.2	94.9	386.0	300.0	410.0	7.9	19.6
Differential count										
Neutrophils	%	56.0	84.0	70.9	8.9	71.0	62.0	80.0	60.2	84.0
Lymphocytes	%	9.0	34.0	19.4	8.0	19.0	11.0	27.0	9.8	32.7
Monocytes	%	2.0	6.0	3.6	1.2	4.0	2.0	4.0	2.0	5.6
Eosinophils	%	3.0	10.0	5.6	2.0	5.0	4.0	7.0	3.8	9.6
Basophils	%	0.0	1.0	0.2	0.4	0.0	0.0	0.0	0.0	1.0
LUC	%	0.0	1.0	0.2	0.4	0.0	0.0	0.0	0.0	1.0
Neutrophils		0.56	0.84	0.71	0.09	0.71	0.62	0.8	0.6	0.84
Lymphocytes		0.09	0.34	0.19	0.08	0.19	0.11	0.27	0.1	0.33
Monocytes		0.02	0.06	0.04	0.01	0.04	0.02	0.04	0.02	0.06
Eosinophils		0.03	0.10	0.06	0.02	0.05	0.04	0.07	0.04	0.10
Basophils		0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
LUC		0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Total concentration										
Neutrophils	× 10 ⁹ /L	3.5	15.1	8.0	3.3	7.0	5.6	8.8	4.6	14.9
Lymphocytes	× 10 ⁹ /L	0.7	4.1	2.0	0.7	2.0	1.6	2.4	1.2	3.5
Monocytes	× 10 ⁹ /L	0.2	0.6	0.4	0.1	0.3	0.3	0.5	0.2	0.6
Eosinophils	× 10 ⁹ /L	0.3	1.2	0.6	0.3	0.6	0.4	0.8	0.3	1.2
Basophils	× 10 ⁹ /L	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1
LUC	× 10 ⁹ /L	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.1
Females (n = 4)										
		Range					Quartile		Percentile	
		Min	Max	Mean	SD	Median	1st	3rd	2.5%	97.5%
Leukocytes	× 10 ⁹ /L	6.5	15.7	10.1	3.4	9.0	7.0	14.2	7.9	10.1
Erythrocytes	× 10 ¹² /L	7.7	10.3	8.7	1.0	8.3	7.8	9.8	11.4	14.5
Haemoglobin	g/L	113.0	147.0	124.0	14.0	117.0	114	140.0	4.0	5.0
Haematocrit	L/L	0.4	0.5	0.4	0.1	0.4	0.4	0.5	45.3	53.0
MCV	fl	45.0	48.0	46.8	1.3	47.0	45.3	48.0	14.0	16.0
MCH	pg	14.0	15.0	14.3	0.4	14.0	14.0	14.8	30.0	33.0
MCHC	g/L	300.0	330.0	310.0	12.0	305.0	300.0	325.0	3216.0	6080.0
Thrombocytes	× 10 ⁹ /L	309.0	403.0	357.8	33.8	359.5	319.5	394.3	7.1	18.3
Differential count										
Neutrophils	%	62.0	84.0	74.5	9.7	76.0	63.5	84.0	63.8	82.5
Lymphocytes	%	9.0	24.0	15.5	6.7	14.5	9.0	23.0	9.0	34.0
Monocytes	%	2.0	4.0	3.0	1.0	3.0	2.0	4.0	2.0	6.0
Eosinophils	%	4.0	10.0	6.8	2.4	6.5	4.3	9.5	4.3	9.6

Table 3 (continued)

		Differential count								
Basophils	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
LUC	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Neutrophils		0.62	0.84	0.75	0.10	0.76	0.64	0.84	0.64	0.83
Lymphocytes		0.09	0.24	0.16	0.07	0.15	0.09	0.23	0.09	0.34
Monocytes		0.02	0.04	0.03	0.01	0.03	0.02	0.04	0.02	0.06
Eosinophils		0.04	0.10	0.07	0.02	0.07	0.04	0.10	0.04	0.10
Basophils		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
LUC		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
		Total concentration								
Neutrophils	×10 ⁹ /L	4.0	13.2	7.7	3.4	6.7	4.6	11.7	4.7	13.8
Lymphocytes	×10 ⁹ /L	0.7	2.0	1.4	0.4	1.5	0.9	1.9	0.9	3.5
Monocytes	×10 ⁹ /L	0.2	0.3	0.3	0.1	0.3	0.2	0.3	0.2	0.6
Eosinophils	×10 ⁹ /L	0.4	0.8	0.6	0.1	0.7	0.5	0.8	0.5	1.1
Basophils	×10 ⁹ /L	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
LUC	×10 ⁹ /L	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
		Males (n = 17)								
		Range					Quartile		Percentile	
		Min	Max	Mean	SD	Median	1st	3rd	2.5%	97.5%
Leukocytes	×10 ⁹ /L	6.0	20.5	11.4	3.7	10.4	9.0	12.5	8.4	9.9
Erythrocytes	×10 ¹² /L	6.1	10.0	9.0	0.9	9.4	8.6	9.6	11.8	14.2
Haemoglobin	g/L	99.0	142.0	127.0	11.0	128.0	120.0	134.0	4.0	5.0
Haematocrit	L/L	0.3	0.5	0.4	0.0	0.4	0.4	0.4	44.0	51.3
MCV	fl	41.0	53.0	45.7	2.6	45.0	44.0	47.0	13.4	15.7
MCH	pg	13.0	16.0	14.3	0.8	14.0	14.0	15.0	30.0	33.0
MCHC	g/L	300.0	330.0	314.0	10.0	320.0	300.0	320.0	2636.0	5972.0
Thrombocytes	×10 ⁹ /L	236.0	608.0	381.1	104.8	390.0	285.0	415.0	8.4	19.8
		Differential count								
Neutrophils	%	56.0	82.0	69.9	8.4	71.0	61.0	78.0	58.6	81.3
Lymphocytes	%	10.0	34.0	20.4	8.0	19.0	12.0	29.0	10.4	33.0
Monocytes	%	2.0	6.0	3.7	1.2	4.0	3.0	5.0	2.0	5.7
Eosinophils	%	3.0	9.0	5.3	1.7	5.0	4.0	6.0	3.4	8.7
Basophils	%	0.0	1.0	0.2	0.4	0.0	0.0	0.0	0.0	1.0
LUC	%	0.0	1.0	0.2	0.4	0.0	0.0	0.0	0.0	1.0
Neutrophils		0.56	0.82	0.7	0.08	0.71	0.61	0.78	0.59	0.81
Lymphocytes		0.10	0.34	0.20	0.08	0.19	0.12	0.29	0.10	0.33
Monocytes		0.02	0.06	0.04	0.01	0.04	0.03	0.05	0.02	0.06
Eosinophils		0.03	0.09	0.05	0.02	0.05	0.04	0.06	0.03	0.09
Basophils		0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
LUC		0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
		Total concentration								
Neutrophils	×10 ⁹ /L	3.5	15.1	8.1	3.3	7.5	5.6	8.8	4.9	15
Lymphocytes	×10 ⁹ /L	1.0	4.1	2.1	0.7	2.0	1.7	2.6	1.4	3.7
Monocytes	×10 ⁹ /L	0.2	0.6	0.4	0.1	0.4	0.3	0.5	0.2	0.6
Eosinophils	×10 ⁹ /L	0.3	1.2	0.6	0.3	0.5	0.3	0.8	0.3	1.2

Table 3 (continued)

		Total concentration								
Basophils	$\times 10^9/L$	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1
LUC	$\times 10^9/L$	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.1

Haematology was performed using flow cytometry with the exception of haemoglobin, which was determined by the cyanmethaemoglobin method. MCH and MCHC were calculated

LUC large unstained cells, *MCV* mean corpuscular volume, *MCH* mean corpuscular haemoglobin, *MCHC* mean corpuscular haemoglobin concentration

sources (e.g. hot-water bottle or battery-powered heat pads) and blankets for the anaesthetised wildcat were beneficial.

Relative arterial oxygen saturation varied between 89 and 100% but stayed mainly between 93 and 99%. As levels > 95% are regarded as normoxic, it was possible to identify lower levels as mildly hypoxic (90–95%) and distinctly hypoxic (< 90%), respectively, prior to visible cyanotic changes at the oral mucous membranes. These levels indicate the initiation of oxygen supply via the nasal oxygen tubes or respirator masks to support oxygen saturation and prevent hypoxic conditions during anaesthesia.

Intravenous catheter placement in the cephalic or saphenous vein at the beginning of the anaesthesia was suitable for blood sample collection and drug administration. It is possible that a catheter placement at a later stage of anaesthesia might have been more difficult due to the expectable decrease in blood pressure. As blood pressure was not measured in the present study, this assumption cannot be backed up. However, as the pulse was always palpable, peripheral blood pressure did not decrease to an unacceptable or critical hypotension.

The weak positive results in serological tests detecting antibodies against FIV and feline coronavirus (1/21) and the positive detection of antigens of FeLV (2/21) in the present study were comparable to the 0% detection of antibodies against FIV and 3/20 FeLV antigen-positive samples from free-living European wildcats in central Spain (Millán and Rodríguez 2009). Moreover, the detection of FeLV antigen was in the range of previous findings (Daniels et al. 1999; Fromont et al. 2000; McOrist et al. 1991) but below the values reported by Leutenegger et al. (1999). In the Spanish study, one wildcat with a weak positive test result was tested positive 1 year later, which highlights that inconclusive/weak positive test results may be regarded positive from a transmittable infectious disease point of view, especially because regularly clinical signs of an FeLV infection seem to be absent, and thus, infected animals are difficult to detect (Millán and Rodríguez 2009). In the present study, re-testing of the wildcat with weak positive test results would have been desirable but was not possible. Therefore, a final statement about the true FeLV status cannot be made. Whether FeLV may be self-sustained in the wildcat population, as stated previously (McOrist et al. 1991), or has been transmitted from domestic cats remains unknown.

Erythrocyte and leukocyte counts were within the range of previous findings reported for captive wildcats and domestic cats (Marco et al. 2000), except the lower counts of lymphocytes in the present study compared to previous results. Lower counts of lymphocytes may be associated with a cortisol stress response as a result of a chronic stress reaction (Moritz 2013; Nelson and Couto 2014) that might have started to develop in the first 1–2 h after trapping (Dhabhar et al. 1995; Davis et al. 2008). Moreover, it is possible that cortisol stress was caused by unspecific natural factors, such as disease-related or environmental factors. The higher eosinophil counts in females compared to males corresponded to previous reports (Marco et al. 2000), but sex-associated lower neutrophil counts were not confirmed in the present study. However, the low female sample size in this study did not allow statistically valid statements and comparisons. In comparison to the captive wildcats (Marco et al. 2000), higher activities of ALT, AST and CK and higher concentrations of cholesterol were detected in the free-ranging wildcats in the present study. Higher activities of AST, CK and ALT may indicate high muscle activity or muscle trauma associated with trapping, injection and handling, e.g. following defence reactions or attempts to escape the trap (Marco et al. 2000; Moritz 2013; Nelson and Couto 2014). In free-ranging Iberian lynx (*Lynx pardinus*) and bobcats, similar increases in AST and ALT activity have been associated with struggling, strenuous exercise and muscle damage from trapping, darting and intramuscular injection (Beltrán et al. 1991; Fuller et al. 1985) compared to captive individuals (Weaver and Johnson 1995). As the increase in ALT activity was below threefold of previously published ALT reference values in captive wildcats (Marco et al. 2000) and therefore regarded as low, the clinical relevance may be negligible according to experiences with domestic cats (Moritz 2013). However, it is possible that wildcats are different from domestic cats in this respect, and the degree of injury due to capture and injection described in this study was sufficient to increase ALT. Moreover, liver diseases with hepatocellular injury (e.g. due to low-grade infections) may also be associated with increased ALT activity, although other indications for liver diseases, such as alterations in bilirubin and bile acid concentrations, are missing (bilirubin) or were not examined (bile acid levels) in the present

study. In contrast, sodium, potassium, chloride, creatinine and urea concentrations, as well as the A/G ratio, were lower than the ranges reported for captive wildcats (Marco et al. 2000). Conversely, the urea concentrations found in the present study were higher than the values previously reported in captive wildcats (Marco et al. 2000). Sex-associated differences, such as the previously reported higher albumin concentrations and A/G ratios (Marco et al. 2000), were not observed in the present study. The relevance of individual differences cannot be assessed completely as the wildcats were not rechecked multiple times but only sampled once. Moreover, the potential influences of anaesthesia could not be quantified, although anaesthesia is necessary for studies in free-ranging carnivores and has also been used in other studies. The slight differences in the blood values from reference ranges for captive wildcats and domestic cats are most likely the result of capture, restraint and handling, as suspected previously (Marco et al. 2000).

In conclusion, the applied anaesthesia protocol facilitated a safe and sufficient clinical examination, biometric measurements and sample collection as well as PIT and radio collar placement in European wildcats, facilitating the first report of haematological and blood chemical values in free-ranging European wildcats.

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Author contribution MG, OS, JL and DF planned the study. DF, LF, IL, MD, OS and JL performed the field work and the data collection. DF, LF, OS and JL analysed the data and prepared the graphs and tables. OS took the photographs. MG, ML and OS accounted for necessary resources (equipment, laboratory facilities, drugs and funding). DF wrote the manuscript together with LF, OS and JL. All authors reviewed and approved the final version of the manuscript.

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Declarations

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Consent to participate All authors contributed to data acquisition and writing of the manuscript.

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Conflict of interest The authors declare no competing interests.

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