Journal of
*Zoological and Botanical Gardens*

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# Hematological and Biochemical Profiles of Nutria (*Myocastor coypus*): Implications for Biodiversity Management and Household Rearing Practices

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**Abstract:** The absence of standardized reference values for wild rodent species underscores the need for comprehensive hematological and biochemical profiles. This study established robust reference intervals (RIs) for *Myocastor coypus* raised in captivity, analyzing 30 nutrias (10 males, 10 females, and 10 juveniles) at a private farm in northeastern Romania. Leukocyte (WBC) counts averaged 11.85 ($10^3/\mu L$) in males, 10.51 ($10^3/\mu L$) in females, and 11.63 ($10^3/\mu L$) in juveniles, indicating a consistent immune response. Hemoglobin was 11.81 g/dL in males, 11.97 g/dL in females, and 15.42 g/dL in juveniles, with hematocrit levels around 45%. Juveniles displayed higher MCH (38.59 pg) and MCHC (38.58 g/dL), reflecting growth-related adaptations. Platelet counts were lower in adults. Biochemical findings showed lower cholesterol (14.89 mg/dL) and higher glucose (236.26 mg/dL) in juveniles, indicating intense energy metabolism. Total proteins were significantly elevated in juveniles (33.17 g/dL). Creatinine and uric acid levels were higher in adults, although calcium exceeded reference ranges in males (12.04 mg/dL). Hepatic enzyme ALT was higher in males. These findings establish baseline health parameters for captive nutrias, aiding in monitoring and improving rearing practices.

**Keywords:** hematology; *Myocastor coypus*; nutria; serum biochemistry



Academic Editor: László Róbert Szemethy

Received: 26 November 2024
Revised: 31 December 2024
Accepted: 9 January 2025
Published: 13 January 2025

**Citation:** Lazăr, R.; Boișteanu, P.-C.; Bolohan, I.; Mădescu, B.M.; Ivancia, M.; Lazăr, M. Hematological and Biochemical Profiles of Nutria (*Myocastor coypus*): Implications for Biodiversity Management and Household Rearing Practices. *J. Zool. Bot. Gard.* **2025**, *6*, 3. https://doi.org/10.3390/jzbg6010003



## 1. Introduction

The coypu (*Myocastor coypus*), commonly known as nutria, is a semi-aquatic rodent native to South America that has been introduced to numerous regions worldwide for fur production and the nutritional qualities of its meat [1–4].

The fur industry, along with zoos, hunting, and the use of the coypu in biocontrol (e.g., for reducing aquatic vegetation), has historically been the main driver of this species' spread. Consequently, coypu farms were established globally, with the first introductions in Europe recorded in the second half of the 19th century [5–7].

In Romania, the first recorded instance of coypu escaping from breeding farms and adapting to the wild dates back to 14 January 1959, in Ada Marinescu Commune, Ilgani Village, located in the Danube Delta [8].

The nutria is often referred to as an "ecosystem engineer" due to its significant impact on habitats. Through its burrowing and feeding activities, the species can alter the physical characteristics of aquatic and semi-aquatic ecosystems. These changes can have dual effects: positively, nutria can create new microhabitats that benefit certain species, enhancing biodiversity; negatively, they can cause degradation of vegetation, soil erosion, and displacement of native fauna, particularly when populations escape captivity and become invasive. Understanding these ecological roles and mitigating potential adverse effects are critical for ensuring sustainable management practices for nutria, both in captivity and in the wild.

In Romania, the farming of nutrias had a well-established tradition in the mid-20th century, primarily for their valuable fur, which was used in the textile industry. During the communist era, nutria farms were numerous and benefited from direct state support. Although the popularity of this activity declined after the 1990s, there is currently renewed interest in nutria farming in households and small-scale farms. The primary product of nutria farming remains the hide, although the meat is considered a secondary product by farmers. However, in the context of the current international culinary landscape, where consumers are increasingly interested in alternative and exotic meats, farm-raised nutria meat could represent a valuable delicacy option in the meat market, alongside the hide [9].

Romania's climatic conditions and local resources make this species well-suited to semi-intensive farming systems, providing an opportunity for farmers to diversify their animal production.

Similar to many other species, such as woodpeckers, ants, or beavers, the coypu is considered an "ecosystem engineer" [10]. That is an organism capable of shaping habitats and altering the physical characteristics of biotic or abiotic matter, thereby regulating resource availability for other species [10–12]. Given its role in agriculture as well as its impact on ecosystems, understanding the physiology of the nutria has become a significant area of research interest.

Assessing hematological and biochemical parameters is essential for evaluating the health status of nutrias, particularly under various farming conditions that may influence their homeostasis, productivity, and well-being.

According to Cohen S. and colleagues (2007), environmental and management factors, such as diet, population density, farming conditions, and water management, significantly influence the physiological and biochemical parameters of farm animals, including nutrias. These factors not only influence growth and development but also have significant implications for the productivity and welfare of these animals. Stress is defined as any psychological, physical, or physiological change that forces individuals to adapt to their specific demands or conditions [13]. Stressors can vary in intensity and duration, being classified as acute, episodic acute, chronic, cumulative, or traumatic, with the potential to threaten an individual's physical and psychological integrity [14].

For instance, a balanced diet supports optimal hematological profiles, whereas poor environmental conditions or high stress levels can lead to adverse biochemical changes that compromise health. However, findings in this field remain varied; some studies suggest that diet type has a more substantial impact on health than farming conditions, although others propose that environmental stressors are the primary determinants of welfare outcomes.

The aim of this study is to evaluate the impact of farming factors, including nutrition, on the hematological and biochemical parameters of nutria raised in household systems (HS). By analyzing blood samples and conducting biochemical assessments, we aim to identify correlations between specific environmental conditions and the health status of these animals. This research is essential as it provides insights into improving agricultural practices for nutria, supporting both animal welfare and productivity.

The findings of this study will have practical implications for farmers seeking to optimize nutria farming practices. Moreover, the results contribute to the existing literature on the physiological responses of nutria under various environmental conditions, advancing evidence-based guidelines for sustainable agricultural practices.

## 2. Materials and Methods

### *2.1. Biological Material*

For this study, 30 nutrias (*Myocastor coypus*) raised in captivity on a private household farm (HS) in northeastern Romania (47°01′37.5″ N 26°25′12.7″ E) were used. The farming system was semi-domestic, managed at an individual level, with each animal housed in separate cages equipped with essential facilities. The study group consisted of 10 adult males, 10 adult females, and 10 one-month-old juveniles. Blood samples were collected from 10 males, 10 females, and 10 juveniles.

### *2.2. Housing Conditions*

The animals were kept in a protected space enclosed by a galvanized wire fence with 30 × 30 mm mesh openings and a height of 2 m, ensuring adequate protection against unauthorized access and external factors. The nutria were housed in standardized cages measuring 100 cm in length, 70 cm in width, and 50 cm in height. Each one equipped with an access door for regular inspections and a galvanized metal bathing basin with a diameter of 50 cm to meet the animals' hygiene needs. On the side opposite the access door, the cage contained a nest made of wooden planks, lined internally with wire mesh to prevent structural damage caused by gnawing.

These measures were designed to ensure the comfort, safety, and physical integrity of the animals, in accordance with animal welfare standards.

These measures were designed to ensure the comfort, safety, and physical integrity of the animals, in accordance with animal welfare standards. In addition to providing adequate living space and essential equipment, the animals were gradually adapted to these conditions. This gradual adaptation helped reduce stress and allowed the animals to acclimate to their environment, ensuring a smooth transition. The cages were regularly monitored for cleanliness, and the water levels in the bathing basins were checked to maintain hygiene. Nutritional needs were also carefully met, with a balanced diet provided to promote health and well-being. This comprehensive approach ensured that the nutrias could express natural behaviors and maintain good physical and mental health, as required by modern animal welfare practices.

### *2.3. Feeding*

One of the advantages of raising coypu is that these rodent mammals are not demanding regarding their diet, as their nutrition consists exclusively of plant-based products [15–18]. At the time of sample collection, the nutrias were fed green fodder, apples, and beets, ensuring a balanced and nutrient-rich diet.

### *2.4. Sample Collection*

Factors to consider during the collection process include the species, age of the animal, obesity index, health parameters, and overall stress levels. The diagnostic results of blood analyses can be influenced by multiple variables, such as sex, age, strain, circadian rhythms, reproductive cycle stage, pregnancy, diet, season, the type of anticoagulant used, and the site of venous puncture [19,20]. Additionally, any venous puncture procedure carries inherent risks for the subject, including potential injuries or even death caused by handling and sedation, as well as risks associated with the collection procedure itself, such as vascular laceration, infection, damage to surrounding soft tissues, hemorrhage, hypotension, and cardiovascular collapse [21].

In this study, blood samples were meticulously collected from 30 nutrias (10 females, 10 males, and 10 juveniles) following the strict guidelines set forth by the General Data Protection Regulation (EU 2016/679) and in full compliance with Directive EU 2010/63/EU on the protection of animals used for scientific purposes. The ethical standards were rigorously adhered to, ensuring the animals' welfare throughout the process.

The blood samples were obtained through a single venipuncture procedure, performed with precision using 20G needles and sterile syringes. Lateral venipuncture of the saphenous or caudal vein was employed to ensure minimal stress and discomfort for the animals. A single blood sample was collected from each animal, minimizing the impact on their health and well-being. For biochemical analysis, the blood was immediately transferred into tubes without anticoagulant, ensuring the integrity of the sample for subsequent testing. Samples designated for hematological analysis were stored at 4 °C for up to 24 h, preserving the necessary conditions for accurate analysis. After collection, the blood samples were centrifuged to separate the serum, which was then stored at −70 °C until further examination. Throughout the entire study, no experimental factors were introduced, and the animals were carefully monitored and maintained in environments that prioritized their comfort and safety. The ethical considerations, combined with the strict adherence to established protocols, ensured that the study was conducted with the highest standards of animal welfare.

### *2.5. Hematological Analysis*

Hematological analyses were performed using an automated URIT 300 Vet Plus analyzer. The hematological parameters determined included: total leukocyte count (WBC), percentage of lymphocytes (LYM%), total erythrocyte count (RBC), hemoglobin concentration (HGB), hematocrit (HCT), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), total platelet count (PLT).

### *2.6. Biochemical Analysis*

Blood biochemical analyses were performed using an automated Cormay Accent 200 S analyzer. The biochemical parameters measured included: uric acid, glucose, creatinine, total proteins, albumin, alanine aminotransferase (ALT), cholesterol, bilirubin, calcium (Ca), phosphorus (P).

## 3. Results

### *3.1. The Results Regarding Hematological Parameters*

In this study, we evaluated the hematological and biochemical parameters of nutria raised in captivity, with the aim of demonstrating the potential influence of farming factors on health. Hematological parameters, including total leukocyte count (WBC), lymphocytes (LYM), erythrocytes (RBC), hemoglobin (HGB), hematocrit (HCT), and other indicators of erythrocyte and platelet profiles, are essential for monitoring immunological status and the oxygen transport capacity in blood. The values obtained from this study allowed for the assessment of any physiological variations that could be correlated with the environmental and management factors of the animals.

The results obtained from the hematological analyses are presented in detail in Tables 1 and 2. These include specific values for each parameter evaluated, providing a clear comparison between the studied groups and highlighting significant differences between the age and sex categories.

**Table 1.** Hematological parameters in adult nutrias.

| Variable | Class | Mean (SD) [a] | Median | RI [b] |
|---|---|---|---|---|
| WBC ($10^3/\mu L$) | Males | 11.85 (1.72) | 11.85 | 11.0–13.1 |
| | Females | 10.51 (0.79) | 10.45 | 9.9–12.9 |
| LYM (%) | Males | 4.45 (1.17) | 4.85 | 4.2–5.9 |
| | Females | 4.11 (0.76) | 4.21 | |
| RBC ($10^6/\mu L$) | Males | 4.64 (0.34) | 4.51 | 3.9–6.0 |
| | Females | 4.63 (0.22) | 4.56 | |
| HGB (g/dL) | Males | 11.81 (1.45) | 12.05 | 8.0–11.4 |
| | Females | 11.97 (0.99) | 11.95 | |
| HCT (%) | Males | 45.63 (4.08) | 45.15 | 39.3–45.1 |
| | Females | 45.96 (1.60) | 45.90 | |
| MCV (fL) | Males | 101.46 (5.56) | 101.70 | 84.0–102.5 |
| | Females | 101.92 (3.68) | 101.20 | |
| MCH (pg) | Males | 26.32 (2.37) | 25.80 | 18.2–23.4 |
| | Females | 25.08 (3.65) | 27.50 | |
| MCHC (g/dL) | Males | 26.15 (2.92) | 26.65 | 18.2–28.8 |
| | Females | 25.72 (1.72) | 27.90 | |
| PLT ($10^9/L$) | Males | 456.10 (228.78) | 550.00 | 543–727 |
| | Females | 513.50 (160.65) | 502.00 | |

[a] SD, standard deviation; [b] RI, reference interval [according to 1].

**Table 2.** Hematological parameters in juvenile nutria.

| Variable | Mean (SD *) | Median |
|---|---|---|
| WBC ($10^3/\mu L$) | 11.63 (0.29) | 11.55 |
| LYM (%) | 18.54 (0.97) | 18.45 |
| RBC ($10^6/\mu L$) | 4.01 (0.09) | 3.99 |
| HGB (g/dL) | 15.42 (0.32) | 15.45 |
| HCT (%) | 45.91 (0.78) | 45.95 |
| MCV (fL) | 114.47 (0.21) | 114.50 |
| MCH (pg) | 38.59 (0.69) | 38.35 |
| MCHC (g/dL) | 33.86 (0.50) | 33.85 |
| PLT ($10^9/L$) | 446.20 (10.29) | 446.00 |

* SD, standard deviation.

The total leukocyte count (WBC) is a crucial indicator for assessing the health status and immune response capacity of this species, playing an important role in the organism's response to various stress factors and infections. In coypus raised in captivity, WBC values are influenced by a variety of environmental and management factors, including access to natural resources such as water. In males, the average WBC was $11.85 \pm 1.72$ ($10^3/\mu L$), slightly higher than in females, where the average was $10.51 \pm 0.79$ ($10^3/\mu L$). Both averages fall within the reference ranges (11.0–13.1 for males and 9.9–12.9 for females). These values indicate a normal immune system state, with no significant pathological variations between sexes, suggesting adequate immune capacity within the breeding environment.

The erythrocyte count was similar between males and females, with an average of $4.64 \pm 0.34 \times 10^6/\mu L$ for males and $4.63 \pm 0.22$ ($10^6/\mu L$) for females, with values remaining within the reference range (3.9–6.0 $10^6/\mu L$). These data suggest an adequate capacity for oxygen transport within the body, indicating stable health regarding erythrocyte production. In males, the hemoglobin concentration recorded an average value of $11.81 \pm 1.45$ g/dL, although in females, it was $11.97 \pm 0.99$ g/dL, both slightly above the reference range (8.0–11.4 g/dL). These values could indicate an adaptation to the environmental conditions or to the physiological needs of the species in captivity, although the elevated levels do not suggest pathology.

The average hematocrit value was 45.63% $\pm$ 4.08 for males and 45.96% $\pm$ 1.60 for females, both slightly above the reference range of 39.3–45.1%. The mildly increased hematocrit level could be a sign of physiological adaptation to the environment or may reflect dietary specifics.

MCV had an average of $101.46 \pm 5.56$ fL in males and $101.92 \pm 3.68$ fL in females, with all values within the reference range (84.0–102.5 fL). This parameter is important for determining the size of erythrocytes and reflects the stability of cell size between the two groups.

In males, MCH had an average value of $26.32 \pm 2.37$ pg, although in females it was $25.08 \pm 3.65$ pg, both values slightly exceeding the reference range of 18.2–23.4 pg. This increase suggests a higher hemoglobin content per erythrocyte, possibly linked to the species' characteristics under captive conditions.

MCHC was $26.15 \pm 2.92$ g/dL in males and $25.72 \pm 1.72$ g/dL in females, with values within the reference range. This stability between sexes indicates uniformity in hemoglobin concentration in erythrocytes, corresponding to normal oxygen transport function.

The platelet count was low in both groups, with an average of $456.10 \pm 228.78$ ($10^9$/L) for males and $513.50 \pm 160.65$ ($10^9$/L) for females, both below the reference range of 543–727 ($10^9$/L). The decrease in platelet count may indicate a physiological adaptation or a specific effect of captive conditions, but without clear evidence of pathology.

*3.2. The Results Regarding the Biochemical Parameters*

Biochemical analyses focused on determining important parameters such as cholesterol, total proteins, total bilirubin (BIL T), creatinine (Creat), and other indicators that provide insight into the metabolic functioning and health of the nutria's vital organs. These biochemical parameters are essential for evaluating liver and kidney functions as well as general metabolism. By interpreting these data in correlation with the observed individual and collective variations in the samples, potential adaptive trends of the species in relation to the growth environment can be highlighted.

The results of the biochemical analyses for adult nutria, both males and females, are presented in Table 3. Table 4 details the biochemical values for the juvenile nutria.

The mean cholesterol level in males was $52.40 \pm 6.82$ mg/dL, and in females, it was $50.00 \pm 8.73$ mg/dL, with both values falling within the reference range (34.1–93 mg/dL). These values indicate a stable lipid profile for both sexes, suggesting an adequate diet and a balanced physiological adaptation to captive conditions.

The total protein level was below the reference range for both groups. In males, the mean was $5.93 \pm 0.51$ g/dL, and in females, it was $5.05 \pm 1.11$ g/dL, compared to the reference range of 6.3–8.9 g/dL.

The mean bilirubin level was $0.93 \pm 0.34$ mg/dL in males and $1.22 \pm 0.25$ mg/dL in females, both within the reference range of 0.3–2 mg/dL. These values suggest normal liver function, with proper elimination of hemoglobin breakdown products, and no signs of jaundice or other liver diseases.

**Table 3.** Biochemical parameters in adult nutria.

| Variable | Class | Mean (SD) [a] | Median | RI [b] |
|---|---|---|---|---|
| Cholesterol (mg/dL) | Males | 52.40 (6.82) | 53.85 | 34.1–93 |
| | Females | 50.00 (8.73) | 50.00 | |
| Total protein (g/dL) | Males | 5.93 (0.51) | 6.00 | 6.3–8.9 |
| | Females | 5.05 (1.11) | 5.35 | |
| Billirubin (mg/dL) | Males | 0.93 (0.34) | 0.95 | 0.3–2 |
| | Females | 1.22 (0.25) | 1.25 | |
| Creatinine (mg/dL) | Males | 2.15 (0.20) | 2.13 | 0.6–5.8 |
| | Females | 3.67 (1.78) | 3.15 | |
| Uric acid (md/dL) | Males | 8.45 (3.54) | 10.00 | 2–3.6 |
| | Females | 7.55 (1.60) | 7.30 | |
| Ca (mg/dL) | Males | 12.04 (0.24) | 12.08 | 7–11.2 |
| | Females | 9.09 (1.53) | 9.65 | |
| ALT (μ/L) | Males | 276.10 (95.55) | 285.00 | 200–399 |
| | Females | 260.00 (50.20) | 260.00 | |
| Albumin (g/dL) | Males | 1.44 (1.17) | 0.80 | 3–6.1 |
| | Females | 3.07 (1.64) | 3.65 | |
| P (mg/dL) | Males | 5.53 (2.80) | 6.70 | 6.1–9.3 |
| | Females | 7.17 (1.52) | 7.35 | |
| Glucose (mg/dL) | Males | 152.80 (37.12) | 162.50 | 120–180 |
| | Females | 119.00 (60.74) | 142.50 | |

[a] SD, standard deviation; [b] RI, reference interval [according to 1].

**Table 4.** Biochemical parameters in juvenile nutria.

| Variable | Mean (SD *) | Median |
|---|---|---|
| Cholesterol (mg/dL) | 14.89 (1.78) | 14.95 |
| Total protein (g/dL) | 33.17 (0.85) | 33.30 |
| Billirubin (mg/dL) | 0.30 (0.13) | 0.30 |
| Creatinine (mg/dL) | 2.18 (0.11) | 2.19 |
| Uric acid (mg/dL) | 4.31 (1.80) | 3.75 |
| Ca (mg/dL) | 9.31 (0.16) | 9.36 |
| ALT (μ/L) | 230.00 (12.25) | 230.00 |
| Albumin (g/dL) | 0.28 (0.04) | 0.29 |
| P (mg/dL) | 6.97 (0.11) | 6.98 |
| Glucose (mg/dL) | 236.26 (2.82) | 236.75 |

* SD, standard deviation.

Creatinine had an average value of 2.15 ± 0.20 mg/dL in males, within the normal range, although in females, it was 3.67 ± 1.78 mg/dL, also within the reference range. This parameter indicates normal kidney function, with no significant variations between sexes, and is an indicator of metabolic stability.

Uric acid levels were elevated, with a mean of 8.45 ± 3.54 mg/dL in males and 7.55 ± 1.60 mg/dL in females, exceeding the reference range of 2–3.6 mg/dL.

Calcium levels were 12.04 ± 0.24 mg/dL in males, above the reference range, and 9.09 ± 1.53 mg/dL in females, within the normal limits. The higher calcium level in males may indicate a specific metabolic variation, without evident signs of bone or metabolic disorders.

ALT (Alanine Aminotransferase) values were 276.10 ± 95.55 μ/L in males and 260.00 ± 50.20 μ/L in females, within the reference range of 200–399 μ/L. These values suggest normal liver activity, with no indications of acute liver damage, consistent with the healthy physiological profile of the nutria in this study.

Albumin showed a significant variation between sexes, with a mean of 1.44 ± 1.17 g/dL in males and 3.07 ± 1.64 g/dL in females, compared to the reference range of 3–6.1 g/dL. This difference may be influenced by nutritional or metabolic factors, as albumin plays a crucial role in substance transport and maintaining oncotic pressure.

Phosphorus levels were below the reference range for males (5.53 ± 2.80 mg/dL) and close to the lower limit for females. These values suggest a potential variation in phosphorus intake, which is necessary for bone health and metabolic functions.

## 4. Discussion

The interpretation of hematological and biochemical parameters in nutria (*Myocastor coypus)* provides a detailed picture of the health and physiological adaptability of these animals raised under semi-intensive conditions. The analysis of these parameters not only highlights the organism's responses to environmental factors and diet but also reveals the physiological differences between young and adult nutria. It is essential to understand how variables related to the rearing space, access to water, and nutritional intake influence the animals' health. The results obtained in this study will be discussed in the following paragraphs, compared to the existing literature, to emphasize the impact of each environmental factor on the key hematological and biochemical parameters.

The WBC (White Blood Cell count) value reflects the body's ability to respond to infections and stress factors and serves as an important indicator of the immune response. In this study, the WBC values for nutria were within reference ranges and stable between males and females, suggesting a balanced immune response, with no significant exposure to stress or pathogens. These results are in line with observations from Jelínek's (2014) study, where nutria raised in controlled conditions with access to a stable environment presented similar WBC values, without obvious pathological variation [22]. In contrast, in more stressful environments, such as those with higher population density or poor hygiene conditions, studies have reported significant increases in WBC in rodents, reflecting an activated immune response.

These findings are consistent with other studies, such as Jelínek (2014), which demonstrated stable WBC levels in nutria raised under controlled conditions with minimal environmental stress. Access to water, adequate space, and individualized housing have been shown to reduce stress-induced immune responses, which can otherwise manifest as elevated WBC levels. This stability underscores the effectiveness of semi-intensive farming practices in maintaining the immune health of nutria. In contrast, environments with overcrowding or poor hygiene often lead to significant increases in WBC, reflecting heightened immune activation due to stress or infection. Incorporating these management insights into farming practices is essential for optimizing animal health and ensuring consistency in physiological parameters across populations.

Access to a bathing pool and individualized space may explain the stable WBC values in this study, as the animals had the opportunity to reduce stress levels and maintain proper hygiene. This observation is also supported by studies on the effects of stress in semi-aquatic rodents, where access to water and comfortable conditions contributed to maintaining normal WBC values [23].

The young nutria exhibited a WBC value of 11.63 ($10^3/\mu L$), very close to the values observed in adults. This suggests that even at an early age, the juveniles have a robust immune response, reflecting the species' natural adaptability to a semi-aquatic environment. Compared to adults, this stable WBC value indicates an early maturation of the immune system, a trait that may help juveniles protect themselves from infections in similar captivity conditions. Studies on young rodents generally show that a stable white blood cell count is a positive indicator of health and normal development and that adequate environmental conditions can support this stability.

RBC (red blood cell count) is a fundamental hematological parameter that indicates the body's ability to transport oxygen, a crucial aspect for the overall health and metabolic performance of nutria. In our case, the RBC values were within the normal range, suggesting a stable oxygen transport capacity, likely influenced by a balanced diet and appropriate growth conditions. This profile is comparable to the data provided by Martino et al. (2012), who observed that in wild nutria, RBC values can vary depending on access to quality food and adaptability to environmental conditions [24].

In comparison, in captivity environments with no constant access to water or with imbalanced diets, some studies have highlighted a compensatory increase in RBC as an adaptation to oxidative or thermal stress [25].

The RBC value in juveniles is 4.01 ($10^6/\mu L$), slightly lower than in adults. This difference can be attributed to the high growth rate, which can influence erythrocyte production. According to the literature, RBC differences between juveniles and adults are normal in growing mammals, as metabolic requirements and blood volume progressively adjust as animals approach physiological maturity.

Hemoglobin (HGB) and hematocrit (HCT) are essential for evaluating erythrocyte health and the capacity to transport oxygen. In this study, both values were slightly above the reference limits, which may be associated with the positive effects of a balanced diet. Diets that include beetroot and green mass are known for their iron content and other important nutrients for hemoglobin synthesis, thus supporting an optimal hemoglobin value. These observations align with the study by Němeček et al. (2019), which showed that a balanced diet can maintain high levels of HGB and HCT in nutria raised for meat [26].

Furthermore, when compared to other rodents that do not benefit from the same dietary or environmental conditions, the levels of HGB and HCT may be lower, reflecting an adaptation to nutrient deficiencies. This supports the hypothesis that an adequate diet and proper growth conditions significantly contribute to the stability and health of the hematological profile in nutria [27,28].

In juvenile nutria, the hemoglobin concentration (HGB) is higher (15.42 g/dL) than in adults, indicating a compensatory adaptation to support oxygen transport during accelerated growth. The elevated HGB value in juveniles can be interpreted as a physiological mechanism to meet the increased oxygen demands during the developmental phase. Similarly, hematocrit (HCT) is nearly identical between juveniles and adults, suggesting stability in erythrocyte volume and oxygen transport capacity, even at a young age. Literature indicates that higher HGB in juveniles is a common adaptation to compensate for a slightly lower erythrocyte count, a feature also observed in juvenile nutria.

Juvenile nutria present a significantly higher MCV value of 114.47 fL compared to adults, reflecting larger red blood cells. This profile is commonly found in young animals, whose red blood cells are less compact and have a larger volume as the body begins to establish efficient hematopoiesis. MCH (38.59 pg) and MCHC (33.86 g/dL) are also higher in juveniles, suggesting a greater amount of hemoglobin per cell and a higher concentration of hemoglobin. These adaptations may support accelerated metabolic growth. Compared to adults, these values reflect a necessary adaptation to maintain oxygen transport during the critical growth phase, similar to adaptations observed in other rodents during early life stages.

The total platelet count (PLT) was below the reference range, which may suggest a low level of platelet activation and, consequently, a general state of good health without excessive stimulation of the coagulation system. According to specialized studies, a lower platelet count can be observed in rodents living in comfortable captivity conditions, with low stress and reduced infection risks [29]. Additionally, access to a bathing pool, present in the growth conditions of this study, contributes to reduce the potential for injuries or inflammation that could stimulate an increase in platelets.

Juvenile nutria have a platelet value (PLT) of 446.20 ($10^9$/L), slightly lower than that observed in adults. This value can be explained by a lower rate of platelet activation and a reduced physiological need for coagulation compared to adult animals.

When comparing the hematological values of the juveniles with those of the adults, we observe a series of age-specific physiological adaptations that support the metabolic and immune requirements of the young animals. Differences in RBC, HGB, MCV, and PLT are characteristic of the growth phase and indicate a well-adapted physiological system that meets the specific needs of early age. These observations are consistent with the literature, which emphasizes that during the early stages of life, many mammal species, including nutria, present distinct hematological profiles to support rapid development and adaptation to the environment.

The lower platelet counts observed in this study, although within acceptable ranges for healthy individuals, may suggest reduced coagulation activity due to the absence of significant physical stressors or injury risks in captivity. This trend aligns with findings by Němeček et al. (2019), which noted similar reductions in PLT levels in nutria raised under stress-minimized conditions. To ensure long-term stability, dietary adjustments may be beneficial, such as incorporating micronutrients like vitamin K, known for supporting platelet production and function. Additionally, omega-3 fatty acids, which have anti-inflammatory properties, could help maintain an optimal balance in coagulation pathways. Regular monitoring of PLT levels in farmed nutria would help detect early signs of potential deficiencies or shifts that might compromise health.

Serum cholesterol in adult nutria was within the reference range, suggesting a stable metabolic state and efficient adaptation to a diet based on green matter, apples, and beets. A study by Němeček et al. (2019) observed that a diet rich in plant nutrients contributes to maintaining an optimal cholesterol level in rodents raised in captivity [26].

The reduced levels of total proteins observed in adults, which are below the reference range, may indicate a specific nutritional need for higher-quality proteins, possibly unmet by the predominantly plant-based diet. Martino et al. (2012) highlighted the importance of animal-derived proteins or supplements rich in essential amino acids to support the general health and balanced biochemical profile of rodents [24].

The significant difference in cholesterol levels between adults and juveniles highlights the metabolic distinctions driven by growth-related demands. Juveniles exhibited notably lower cholesterol levels, reflecting the rapid utilization of lipids for tissue development and energy production during their growth phases. Turner et al. (2019) reported similar findings in other semi-aquatic rodents, emphasizing the need for tailored nutritional interventions for juveniles. Providing lipid-rich dietary components, such as seeds or vegetable oils, could support their metabolic needs although maintaining overall health.

For adults, the stable cholesterol levels within reference ranges suggest that the plant-based diet provided in captivity meets their basal metabolic requirements. However, it is crucial to monitor lipid metabolism in nutria, as deviations over time could indicate imbalances or stressors affecting their health. Balancing dietary fat intake with sufficient fiber and protein sources will ensure a sustainable physiological state for both growth and maintenance.

However, the slight variations between sexes can be attributed to metabolic and hormonal differences. Previous studies on semi-aquatic rodents, such as beavers (*Castor canadensis*), have shown that males frequently exhibit slightly higher cholesterol levels due to the different energy demands imposed by territorial activities and reproductive competition. Testosterone, a predominant hormone in males, can influence lipid metabolism by stimulating hepatic cholesterol synthesis, which could partially explain the higher values in male nutria. Moreover, the nutria diet, based on green fodder, beets, and apples, is rich in dietary fiber, which helps maintain low cholesterol levels by reducing its absorption in the intestinal tract, as demonstrated in other studies on the effect of fiber in rodents. However, moderate cholesterol levels reflect an efficient balance between dietary intake and endogenous cholesterol metabolism, supporting the metabolic adaptability of the species to semi-intensive conditions. Compared to other semi-aquatic rodents, such as wild nutria or beavers, the cholesterol values observed in this study are similar to those reported in healthy individuals raised in captivity, confirming that semi-intensive conditions provide a diet and environment conducive to maintaining lipid homeostasis. However, further studies could explore in more detail the impact of diets enriched with sources of unsaturated fats on the lipid profile of nutria raised in captivity [30].

The total protein level observed below the reference range in both groups (males and females) suggests a potential nutritional deficiency in the current diet, which is based on green fodder, apples, and beets. Total proteins primarily reflect the intake and metabolism of dietary proteins, but they are also influenced by liver function, hydration, and inflammatory processes. In this context, the lower values observed in females compared to males could be related to different metabolic requirements, such as those associated with reproduction and lactation. Compared to other semi-aquatic rodents, the reduced total protein values could reflect a specific deficiency in essential amino acids in the provided diet, as demonstrated by studies on beavers (*Castor fiber*), where inadequate protein intake negatively affected serum total protein levels and overall health. A possible explanation for the low levels of total proteins could be the dietary limitation in high-quality protein sources. The nutria, being a species adapted to consuming a variety of foods in the wild, would benefit from the inclusion of protein-rich feed in its diet, such as legumes (soybeans, peas) or protein concentrates. Additionally, the introduction of dietary supplements specifically formulated for rodents could increase the intake of essential amino acids and improve the serum level of total proteins. The observed difference between males and females can be partially explained by different metabolic prioritization. In females, the requirements for supporting reproduction and lactation may increase the rate of protein utilization, which could lead to lower serum levels. Previous studies on other rodents have demonstrated that breeding females require an increased protein intake to compensate for the losses associated with milk production and physiological support for the offspring [31].

The serum levels of bilirubin are within the reference range, indicating normal liver function. These values suggest a good adaptation of the metabolism in captivity and optimized growth conditions.

The serum creatinine level is within normal limits for nutria, indicating stable renal function. The predominantly plant-based diet has not negatively affected this parameter.

Uric acid levels are elevated in adult nutria, exceeding the reference range. These values may result from increased purine metabolism, influenced by a diet rich in plant-based foods, particularly in rodents with specific metabolic traits.

Calcium levels were higher in males, indicating an accumulation of minerals possibly linked to enhanced absorption specific to the species. Elevated calcium levels may reflect an adaptation to the specific diet without indicating pathology.

A higher calcium level in males could be linked to the influence of sex hormones, particularly testosterone, which is known for its role in stimulating bone metabolism and increasing calcium reabsorption. Studies on other semi-aquatic rodents, such as beavers, have shown similar variations in calcium levels, with higher values in males during the reproductive period, suggesting a correlation with hormonal activity. Additionally, dietary calcium intake plays a crucial role. Green forage-based feed, such as alfalfa or beet, can contribute to a higher calcium intake. Males, having a larger body mass and, implicitly, increased metabolic demands, can absorb calcium more efficiently to support physiological activities, including maintaining bone mass and muscle functions. Females exhibit calcium levels within the reference range, indicating an efficient use of calcium for the specific needs of the organism, including supporting reproductive functions. However, the lower levels compared to males may reflect a redistribution of calcium to support pregnancy and lactation, physiological priorities that could temporarily influence serum calcium homeostasis. In other semi-aquatic rodents, such as muskrats (*Ondatra zibethicus*), calcium levels are influenced by the available diet and the season. Studies show that access to calcium-rich sources, such as aquatic plants, can support high serum calcium levels, especially in males during periods of increased activity. High calcium levels in males do not suggest a pathology, but they may indicate a more efficient use of dietary calcium or a sex-specific increased metabolic requirement [32]. To ensure optimal balance, continuous monitoring of the calcium-phosphorus ratio in the diet is recommended, as an imbalance can affect bone health and overall metabolism. In addition, future studies could explore the influence of season and reproductive stages on calcium levels in both sexes [32].

Serum ALT levels fall within the reference range, reflecting healthy liver function. A stable ALT level suggests adequate adaptation to environmental conditions and supports normal liver function.

Albumin is low in males, possibly due to a diet with a reduced content of quality proteins. The predominantly plant-based diet may require supplementation to ensure adequate protein balance.

The very low levels of albumin observed in males may indicate a dietary deficiency in high-quality proteins, considering that albumin is synthesized in the liver from essential amino acids obtained from the diet. Additionally, the higher energy requirements in males for maintaining body mass and behavioral activities, such as territory defense and reproductive competition, could redistribute metabolic resources, leaving less available for albumin synthesis. Although albumin levels in females are closer to the reference range (3.07 $\pm$ 1.64 g/dL), the observed fluctuations may be associated with the physiological role of females in reproduction and lactation. These processes involve or require high metabolic demand, which can temporarily affect the synthesis and utilization of albumin. Studies on other semi-aquatic rodents, such as muskrats (*Ondatra zibethicus*), suggest that females prioritize protein resources for supporting their young, which may contribute to lower albumin levels during certain periods of the reproductive cycle. In other semi-aquatic rodent species, such as beavers (*Castor canadensis*), the variations in albumin between sexes are less pronounced, highlighting a potential different metabolic adaptation in nutria under captive conditions. Additionally, stress or environmental conditions can amplify these differences in protein metabolism [33].

Phosphorus levels in males are below the reference range, suggesting a potential deficiency related to dietary phosphorus intake, with implications for bone health and overall metabolism.

The more pronounced deficiency in males may reflect different metabolic requirements, such as higher needs for maintaining muscle and bone mass. In females, phosphorus levels near the lower limit could be influenced by the redistribution of metabolic resources to support reproductive and lactation functions. Studies on other semi-aquatic rodents, such as beavers, have demonstrated a link between reproductive demands and fluctuations in serum phosphorus levels, highlighting the importance of dietary supplementation in such situations. The unbalanced ratio between calcium and phosphorus can affect mineral metabolism and bone health. The higher calcium levels observed in males compared to the lower phosphorus levels suggest a possible interference in phosphorus absorption, which could be amplified by the predominantly plant-based diet. Plants, such as beets and green fodder, contain phytates, which can inhibit phosphorus absorption, contributing to the mineral imbalance. In the case of muskrats (*Ondatra zibethicus*), it has been observed that access to natural water sources and phosphorus-rich vegetation can support higher levels of this mineral [34,35]. The differences compared to nutria raised in captivity highlight the importance of adjusting the diet to mimic the intake from the natural environment. Low phosphorus levels necessitate a diet with sources rich in this mineral, such as bone meal or balanced mineral supplements, which can be added to the daily ration to correct the deficiency. It is also essential to monitor the calcium-phosphorus ratio in the diet to prevent any imbalances that could affect bone health or overall metabolism.

Glucose levels are within the reference range, suggesting stability in carbohydrate metabolism. Constant access to fresh, varied food helps prevent glucose fluctuations.

The biochemical results show stable metabolic health in adult nutria, influenced by the captivity conditions and specific diet. The plant-rich diet maintains the stability of certain parameters, but adjustments may be needed to optimize the intake of essential proteins and minerals, thus ensuring the long-term health of the animals.

Biochemical results for juvenile nutria provide insight into their metabolism and health during early developmental stages. Comparing these results to those of adults reveals specific physiological adaptations based on age and growth requirements.

In juveniles, cholesterol values (14.89 mg/dL) are significantly lower than in adults, reflecting a difference in lipid metabolism specific to the growth phase. Lower cholesterol in young rodents is typical for an active metabolism, where lipids are quickly utilized for organ and tissue development rather than being stored.

Total proteins are much higher in juveniles (33.17 g/dL) than in adults, indicating a higher protein requirement for tissue synthesis and intense growth processes. The elevated protein levels may reflect an adaptation to the increased need for essential amino acids at this stage.

Bilirubin is lower in juveniles (0.30 mg/dL) compared to adults, indicating a less active process of red blood cell breakdown at a young age. Bilirubin levels may increase with age as the body reaches a mature and balanced metabolic rate.

Creatinine levels (2.18 mg/dL) in juveniles are similar to those in adults, suggesting stable renal function from an early age. Constant creatinine values during the growth period are associated with proper kidney development and function.

Juveniles exhibit higher uric acid levels (4.31 mg/dL), significantly greater than in adults. This increase may be linked to an intense protein metabolism during the growth phase, characterized by active protein synthesis and breakdown.

Calcium levels (9.31 mg/dL) are similar between juveniles and adults, indicating stable intake necessary for bone formation. Stable calcium levels suggest efficient absorption to support skeletal development and prevent hypocalcemia during critical growth periods.

ALT values are slightly lower in juveniles (230.00 μ/L) than in adults, suggesting healthy liver activity adapted to the lower metabolic requirements of young animals. The lower ALT value reflects stable liver function, without exposure to major hepatic stressors.

Albumin is low in juveniles (0.28 g/dL), which may reflect increased protein usage for growth and development at the expense of albumin synthesis. Growing animals may have reduced albumin levels as a consequence of prioritizing amino acids for protein synthesis and tissue formation.

Phosphorus levels are almost identical between juveniles and adults, with a value of 6.97 mg/dL, ensuring healthy bone formation. Stable phosphorus levels are essential for skeletal development in young rodents, helping prevent bone deficiencies during rapid growth.

Juveniles have significantly higher glucose levels (236.26 mg/dL) compared to adults, indicating intense carbohydrate metabolism to support rapid growth and high energy activity. Elevated glucose levels are a response to the high energy demands typical of this developmental phase.

The biochemical results for juveniles show notable differences compared to adults, suggesting physiological adaptations necessary to support growth and development. Elevated total protein, uric acid, and glucose levels reflect the high metabolic and energy demands of juveniles.

These results highlight the critical role of managing growth conditions and maintaining a balanced diet to sustain physiological parameter stability and overall health in captive nutria.

This study provides novel insights into the ecophysiology of semi-aquatic mammals, making significant contributions to our understanding of the basic hematological and biochemical profiles of nutria under various environmental conditions and at different life stages. However, the generalizability of the obtained results may be influenced by the exploratory nature of the research and certain methodological limitations, such as a small sample size and the absence of control variables, such as specific diet or exposure to pollutants. Future research, based on a more robust experimental design and a larger, more representative sample, could strengthen and expand the conclusions of the present study, providing more detailed information about nutria physiology and the impact of stressors on their health.

## 5. Conclusions

The study of hematological and biochemical parameters in nutria (*Myocastor coypus*) raised in a private mountain household emphasizes the importance of the rearing environment for the health and physiological adaptability of this species. Compared to traditional farms in southern Romania, where the climate and access to water are more favorable, the nutria in this study benefited from controlled conditions, although the access to optimal water and movement space may have been limited.

Nutria are semi-aquatic, and permanent access to larger water basins could contribute to improved well-being and enhanced physiological health, reducing stress and promoting better hygiene. Although the basins in this study provided the necessary minimum, expanding them would improve skin health and behavioral adaptability in nutria.

Individual cages, although equipped to prevent damage from gnawing and with space for bathing, are smaller compared to semi-natural conditions. Expanding these cages would support natural behaviors, reduce stress, and contribute to the stability of physiological parameters. Thus, for nutria raised in private households in mountainous areas, improving access to larger basins and expanding cage space would support their health and welfare, especially in colder regions.

The study also suggests the need to adjust the diet, particularly by supplementing with high-quality proteins, to meet the nutritional requirements of the nutria, which are not fully satisfied by the predominantly plant-based diet. This diet, based on green forage, apples, and beets, does not provide sufficient protein and other essential nutrients, which is reflected in the low values of total proteins and albumin. These deficiencies can affect metabolic and immune functions, especially in cold temperatures found in mountainous areas.

However, hematological parameters such as WBC and RBC remained stable, suggesting that the diet provided enough nutrients to maintain a balanced immune response and adequate oxygen transport capacity. Nevertheless, supplementation with additional protein sources, such as legumes, protein supplements, or concentrated feeds, could significantly improve the biochemical profile and support the optimal development of nutria, reducing the risk of long-term nutritional deficiencies. Dietary adjustments, along with improvements in living conditions, would contribute to optimizing the health status of nutria and stabilizing their hematological and biochemical parameters, thereby supporting healthy and sustainable growth in captive conditions.

These findings highlight the importance of optimizing farming practices to ensure the health and welfare of nutria although minimizing their ecological impact. Implementing tailored dietary strategies, such as supplementing protein and lipid sources, can address the specific metabolic needs of different age groups and improve productivity. Additionally, maintaining low-stress environments with adequate access to water and space is critical for sustaining physiological stability and reducing potential health issues.

From an ecological perspective, understanding the physiological responses of nutria in captivity can aid in managing their populations effectively, both in farms and in wild habitats. By improving health parameters and reducing the risk of escape or environmental stress, these practices can help mitigate the ecological challenges posed by feral nutria populations. This dual approach—integrating health management with ecological conservation—ensures that nutria farming contributes to sustainable agricultural development although preserving biodiversity.

**Author Contributions:** Conceptualization, R.L.; methodology, R.L., I.B., M.I. and P.-C.B.; software, R.L. and I.B.; validation, R.L., M.L. and P.-C.B.; formal analysis, R.L., M.L., I.B., B.M.M. and P.-C.B.; investigation, R.L., I.B. and B.M.M.; data curation, M.L., M.I. and P.-C.B.; writing—original draft preparation, R.L.; writing—review and editing, R.L., M.L., M.I. and P.-C.B.; supervision, R.L. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** Regarding the approval of the experiment, we would like to confirm that the study was conducted with the approval of the relevant national authority. Approval was obtained under the title "Bioethical Committee Statement no. 53 per 2 October 2023", in accordance with current regulations, to ensure compliance with ethical standards and the welfare of the animals involved in the research. In this study, blood samples were collected from 30 nutria (10 females, 10 males, and 10 juveniles), in accordance with the General Data Protection Regulation (EU 2016/679). The samples were obtained through puncture of the saphenous or caudal vein, using standardized techniques, and the collection procedures adhered to the provisions of Directive EU 2010/63/EU on the protection of animals used for scientific purposes. Throughout the study, the animals were not subjected to experimental factors.

**Data Availability Statement:** The data present in this study are available on request from the first author and corresponding authors.

**Conflicts of Interest:** The authors declare no conflict of interest.

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