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Research Article

Associations between Animal and Herd Management Factors and Urinary Tract Disease in Mink (Neovison Vison)

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Abstract

Mink urinary tract disease (MUTD) causes fatal disease in post-weaning mink kits and mortality rates can vary substantially between farms. MUTD is a disease complex associated with urolithiasis and urinary tract infection. In an exploratory observational study, the occurrence of MUTD and associations with potential animal and management factors were investigated on 20 Danish mink farms. A total of 321.781 mink kits were included in the study. Out of 2.676 mink kits died during the month of July a total of 851 were diagnosed with MUTD. Urolithiasis was diagnosed in 46% of the kits. The majority (98%) of uroliths samples from mink kits diagnosed with MUTD were identified as struvite stones. Staphylococcus delphini group A was isolated from 60% of pure cultures and 21% of mixed cultures obtained from bladder swabs from kits with MUTD. By use of univariate linear regression (continuous variables) and ANOVA (categorical variables) farm management factors were investigated for association with MUTD.

Average daily feed intake in week 17 (late gestation), average kit weight on day 28 post partum, and the color type black had a significant positive correlation with increased mortality associated with MUTD. Average daily feed intake in week 24 (late lactation), kit weight gain, and the number of daily feedings in June (late lactation) had a significantly negative correlation with increased mortality associated with MUTD. Use of short kits nets and cleaning of cage manure were also significantly associated with MUTD. Feeding management and cage hygiene during the weaning period and kit growth have been identified as potentially important factors for fatal MUTD in mink kits and are proposed as focus areas for future studies of this important production disease in mink.

Keywords: Cystitis; Management; Mink; Neovison Vison; Risk Factors; Urolithiasis

Abbreviations

MUTD: Mink urinary tract disease; *E. Coli: Echcherichia Coli*; *S. delphini: Staphylococcus Delphinispp; Ssp.: Several Species*

Introduction

Mink urinary tract disease (MUTD) has been known as a disease syndrome in farmed mink for several decades and presents as cystitis and/or urolithiasis [1,2]. There is currently no documented protocol for prevention or treatment of MUTD. In published reports regarding disease prevalence mortality rates vary substantially between farms [2,3] and in between production years [4]. New evidence suggest that *Staphylococcus delphini* group A is an important pathogen associated with development of MUTD, though in some cases sterile bladder specimens are sampled from mink with macroscopic pathological lesions of MUTD [2]. These negative bacterial culture results do not exclude a primary bacterial etiology and may be the result of previous microbial clearing or unculturable bacterial agents.

Struvite has been identified as the primary type of calculus associated with MUTD in several investigations [1,2,5]. Struvite precipitates in alkaline urine of pH 6.8-7.0 and above [6,7]. It is not known, if struvite formation in mink may occur in a sterile environment as reported for ferrets [8] and cats [7] or if stone formation is initiated by bladder infection with urease producing bacteria elevating urine pH [6]. Feeding pattern [9] and feed intake [10] have been shown to affect the urinary pH in cats. If sterile struvite formation occurs in mink, feed management on mink farms, and mink kit weight and weight gain could be associated with disease. Additionally, the use of urine acidifiers as ammonium chloride may impact urinary pH and affect prevalence of urinary tract disease [11,12]. Water intake is considered to be associated with struvite formation in cats [13,14]. In sows adequate water supply and quality are considered important for treatment and prevention of cystitis [15].

Cage hygiene and cleaning practice may affect bacterial loads in the close environment of the kits. To prevent newborn mink kits falling through the cage thread farms use kit nets (a net with fine mesh covering the cage bottom) from around the time of birth until the kits are approximately five weeks of age. Because of these nets, manure can accumulate inside the cage. Farm routines, including the time intervals between manure removal or the period of time finer meshed nets are kept on the cage floor could directly affect microbial load in the immediate environment of the mink kits and may affect the risk of cystitis caused by ascending infection.

Even though it has been speculated that management may potentially impact development of urinary caliculi and urinary tract infection in mink, there are to our knowledge no previously published investigations of associations between management practice on farms and MUTD. In this explorative observational study, the occurrence of MUTD among mink kits found dead were recorded and related to animal and management factors on 20 farms in Southern Denmark. Furthermore, the microbial agents and mineral composition of uroliths associated with MUTD cases were determined.

Materials and Methods

Study design and farms

An observational study was conducted from 1st of April to 28th of October 2018 on commercial mink farms (n = 20). All mink farmers (n = 25) using the same advisory veterinarian (the primary investigator) where asked to participate in the study. Twenty-one owners agreed to be enrolled in the study. One farm was closed down early in the investigation leaving 20 farms housing a total of 62.626 breeding females. The final study group included a total of 321.781 mink kits housed on the 20 farms on 1st of July. Mink kits were housed in pairs (standard cages) or in groups of three to four mink (double cages) after 10 weeks of age. Housing was according to legislation and standards for mink production in Denmark. The commercial standard-production cage system used in Denmark at the time of this study, have been previously described [16]. Each cage was additionally equipped with an elevated platform (a shelf) and a moveable soft plastic tube, according to Danish regulations for the keeping of mink. The mink were fed commercial mink feed supplied by two feed kitchens Records of the exact feed quantity (kg) and energy (kcal/100g) delivered to the farms were obtained directly from the feed kitchen throughout the investigation. Weekly farm reports of animal totals were obtained from the farms. Under the assumption of minimal feed waste on mink farms, the average of daily feed energy (kcal) intake per animal was calculated on weekly basis for each farm. Energy intake was presented per week number of year. The average was calculated by the number of breeding females to represent the feed energy intake per female and litter.

Interview based data

With the purpose of recording farm procedures with optimal accuracy, farm data were assembled in a combination of weekly telephone interviews and a final interview in-person at the end of the study. The data recorded included farm size (number of breeding females), color types of breeding females, weaning procedures, water data (water supply, type of water nipple, and availability of extra water supply at the nest box), feeding pattern and kit age at feed introduction, use of feed additives (dose, time of use, and frequency) and procedures for kit nets in the cages (use of short nets, procedures for changing, disinfecting, and manure removal of nets in addition to time of final removal).

Kit weights

On each farm the average weight of male and female kits at day 28 after birth was obtained from litters with six to nine kits of first year females (color type brown). On two farms not breeding brown mink, the kits included were of another color type. If less than 50 litters met the inclusion criteria all litters were included. If more than 50 litters fulfilled the criteria a sample of 50 litters was randomly selected. The included litters were marked and weighed again at day 95 after birth. All weights were recorded using the same scale (Semiauutomatic Mink Scale, FarmGain). An average weight gain in male and female mink kits on each farm was calculated.

Water quality

Between the 18th and 21st of June mink drinking water samples were collected from all farms. One pre-circulation sample was obtained where the water supply enters the farm and one sample was collected after circulation. The samples were analyzed at Analyselaboratoriet, Dansk Pelsdyr Foder a. m. b. a., Denmark. Bacterial limit values were set as previously described [17]: 200/mL for a total germ count, 5/mL for fluorescence germ counts, and 0/100 mL for coliform bacteria and thermo stabile coli counts. Threshold of nitrite and nitrate values was set according to the limits for human drinking water at 1 mg/L and 50 mg/L, respectively. The storage and transportation of samples were conducted according to laboratory guidelines.

Gross pathology, microbiology and urolith analysis

Throughout July all dead or euthanized mink kits were sampled daily and stored at -20 °C until post mortem examination using standardized gross pathological urological evaluation as previously described [2].

Urinary bladder swabs were sampled on the farm and stored at 5 °C until routine culture analysis (0.5 to four days). As previously described, samples were smeared on blood agar plates (blood agar base (Oxoid) supplied with 5% sterile bovine blood) and anaerobically incubated for 24 h at 37 °C and final microbial identification was achieved by MaldiTof-MS Vitek MS system (MALDI-TOF) [2,18]. Urolith mineral composition analysis was conducted at Minnesota Urolith Center by quantitative methods using polarizing light microscopy, infrared spectroscopy, or X-ray diffraction [19].

Statistical methods

Mean and standard deviation over all farms were reported for continuous explanatory variables (energy intake week 15-26, weight day 28 and day 95, and weight gain). The association between prevalence of MUTD and numerical predictors was analyzed using univariate linear regression. Analysis of variance (ANOVA) was used to compare prevalence of MUTD between groups given by categorical management variables. Observations were weighted inversely proportional to the total number of animals on the farm. By means of the Welch two-sample t-test the difference between mean water pH from farms using public and well drinking water was tested. Statistical significance was defined at a 5% significance level ($p < 0.05$).

Results and Discussion

Results

In total 2.676 mink kits died or were euthanized throughout July on the included farms (n = 20) with 851 mink kits being diagnosed with MUTD postmortem (32%). Eighty-four percent of the mink kits with MUTD were males (n = 713) and 16% were females (n = 137). For one kit with MUTD the gender was not registered. A prevalence of MUTD postmortem was calculated for each farm based on the number of kits with MUTD postmortem in July and the total count of mink kits on 1st of July. The results are illustrated by a dot plot in figure 1. Macroscopic gross pathological findings associated with MUTD diagnosed on the included farms are summarized in table 1. Nephrolithiasis was diagnosed in 9% (n = 36) of mink kits with urolithiasis (n = 393).

The average daily energy (kcal) intake per female or female and litter per week for all included farms is shown in figure 2 (week 15-26). In table 2, the mean and standard deviation for all farms is listed. By linear regression analysis, decreased feed energy intake per female in week 17 (23rd to 29th of April) ($p = 0.031$) and increased feed energy intake per female and litter in week 24 (11th to 17th of June) were significantly associated with a reduction in prevalence of MUTD ($p = 0.049$). No associations ($p > 0.05$) were found between feed energy consumed and prevalence of MUTD in any of the remaining weeks investigated (w. 15-26). Results are displayed in table 2.

Increasing number of daily feedings (average) in June was significantly associated with lower prevalence of MUTD by means of univariate linear regression analysis ($p = 0.048$). There was no significant association ($p = 0.418$) between prevalence of MUTD and the age of kits when feed was introduced for the kits (between 25 and 30 days).

Three farms did not use ammonium chloride as a feed additive. The remaining 17 farms all used an ammonium chloride feed supplement in low concentration (2‰). Three farm used ammonium chloride once a day, the remaining farms used the supplement at all feedings. Two farms used a B-vitamin feed supplement during the investigation period. Results of linear regression analysis and ANOVA on variables regarding ammonium chloride and weaning are listed in table 2.

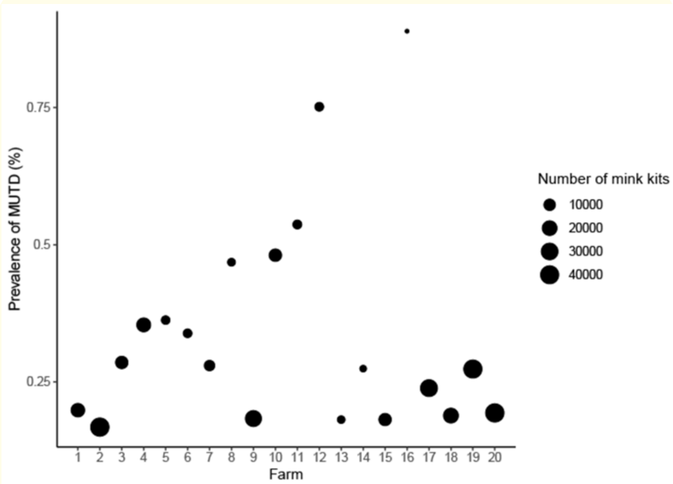

Figure 1: Dot plot illustrating the prevalence MUTD (mink urinary tract disease) postmortem on 20 mink farms in July. Number of mink kits = the number of mink kits 1st of July.

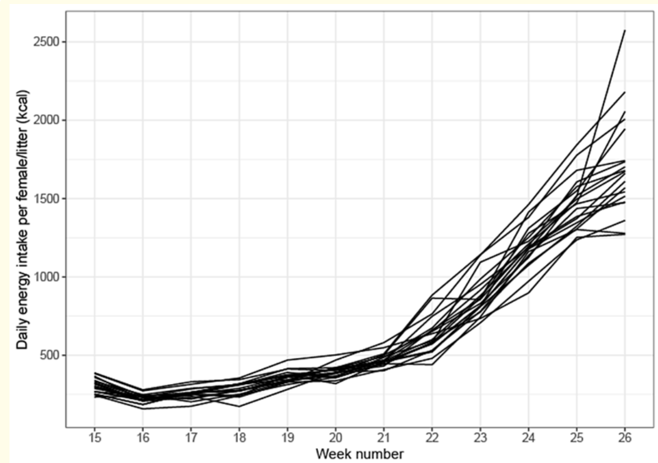

Figure 2: The average daily energy (kcal) intake per female or litter per week as a function of week number (15-26) displaying 20 farms.

		Macroscopic pathological findings					
	Urinary bladder						
Mink kits	Mucosal edema	Mucosa hemorrhage	Hematuria	Pyuria	Urethral obstruction[a]	Urolithiasis	Pyelo-nephritis
N	523	639	689	640	614	393	67
%	61%	75%	81%	75%	72%	46%	8%

Table 1: Summary of gross pathological findings in mink kits with urinary tract disease leading to mortality (n = 851).
[a] Defined as a distended bladder filled with content.

Continuous variables			Linear regression	
Feed energy	Mean (SD)		p-value	β_1
Week 15	304.9 (46.5)		0.437	
Week 16	223.1 (28.8)		0.954	
Week 17	256.1 (34.8)		0.031	2.230e-05
Week 18	282.9 (42.4)		0.321	
Week 19	359.8 (41.1)		0.407	
Week 20	395 (42)		0.905	
Week 21	471.6 (42.9)		0.98	
Week 22	626.7 (116.9)		0.324	
Week 23	875.5 (127.9)		0.098	
Week 24	1,195.8 (136.1)		0.049	-3.872e-06
Week 25	1,472.9 (167)		0.085	
Week 26	1,702.2 (319.9)		0.112	

Kit weight				
Females' day 28	163.3 (15.1)		0.008	5.908e-05
Males' day 28	178.3 (19.1)		0.01	4.809e-05
Females' day 95	1369.9 (56.8)	-	0.067	
Males' day 95	1969.4 (102.8)	-	0.08	
Weight gain females	1206.0 (65.3)		0.031	-1.093e-05
Weight gain males	1790.5 (107.7)		0.042	-6.479e-06
Fur color type	(n)	%		
Brown (n)	21049	33.6	0.824	
Black (n)	1595	2.5	0.007	0.007
Mahogany (n)	1948	3.1	0.938	
Silverblue (n)	10535	16.8	0.112	
White (n)	11030	17.6	0.695	
Palomino (n)	7258	11.6	0.638	
Pearl (n)	4318	6.9	0.228	
Pastel (n)	1950	3.1	0.574	
Redglow (n)	1050	1.7	0.976	
Others	1893	3	-	
Date variables				
Feeding management	Earliest date	Latest date		
Ammonium chloride additive, start	5th of June	16th of July	0.317	
Ammonium chloride additive, finish	6th of July	1st of October	0.522	
Weaning				
Kit weaning, start	13th of June	27th of June	0.48	
Kit weaning, finish	24th of June	9th of July	0.492	
Kit net hygiene				
Remove kit nets, start	25th of May	7th of June	0.961	
Remove kit nets, finish	6th of June	2nd of July	0.883	
Categorical variables, (n = farms)				
Feeding management	Yes	No		
Short term daily fast in June (n)	4	16	0.09	
Use of ammonium chloride (n)	17	3	0.374	
Kit nets hygiene				
Short nets (n)	5	15	0.043	0.002

Table 2: Results of linear regression analysis and ANOVA.

β_1 is displayed for variables with significant results of linear regression analysis ($p < 0.05$).

Kit weights

Fifty litters fulfilled the criteria for weighing group inclusion on six farms. On the remaining farms between 10 and 48 litters were included. Death of mink kits within weighing groups varied greatly between farms from the first to the second weight recording. The farms lost from 2% to 23% of female kits and from 0 to 27% of male kits within the weighing groups. For both female ($p = 0.008$) and male ($p = 0.01$) mink kits increased mean body weight at the age of 28 days was found correlated with higher prevalence of MUTD (Table 2). A negative correlation was found between prevalence of MUTD and average weight gain (female: $p = 0.042$, male: $p = 0.031$) from day 28 to day 95.

Color type

The total distribution of the included breeding females according to fur coat color type is listed in table 2 together with a test for correlation between the percentages of females in each color type and the farm prevalence of MUTD. Higher percentage of females of the color type black was significantly associated with increased prevalence of MUTD ($p = 0.007$).

Water supply

Results of water pH and bacterial quality analysis are summarized in table 3. No farms had nitrite levels beyond threshold. In one farm nitrate levels were above threshold in inlet and outlet water at 50.5 mg/L and 61.36 mg/L. No significant correlation was found between the pH or total germ count (GC) of inlet (pH: $p = 0.655$, GC: $p = 0.621$) or outlet (pH: $p = 0.933$, GC: $p = 0.772$) drinking water and the farm prevalence of MUTD.

Mean pH of water sampled from farms with public water supply was significantly higher ($p < 0.05$) than samples from farms with well drinking water (Table 3).

		Inlet water			Outlet water		
	N	Mean (SD)	Min	Max	Mean (SD)	Min	Max
pH, total	20	7.4 (1.0)	4.95	8.55	7.5 (1.0)	4.84	8.53
pH, public water	12	8.0 (0.4) [a]	7.32	8.55	8.2 (0.2) [a]	7.89	8.53
pH, farm well	8	6.4 (0.8) [b]	4.95	7.33	6.5 (0.9) [b]	4.84	7.71
		Groups by limit value (LV*)					
		< 1	1 to LV	> LV	< 1	1 to LV	> LV
Total bacterial count (n)	20	11	8	1	7	12	-
Florescence germ count (n)	20	16	2	2	17	3	0
		< LV	> LV		< LV	> LV	
Coliform bacteria count	20	19	1		17	3	
Thermo stabile coli count	20	20	0		17	3	

Table 3: Summary of water pH and bacterial quality of inlet and outlet water on mink farms (n = 20).

[a,b] Different superscript letters within columns illustrates significant difference between means by the Welch two-sample *t*-test ($p < 0.05$). LV = Limit value. Total germ counts: 200/mL, fluorescence germ counts: 5/mL, coliform bacteria and thermo stabile coli count: 0/100 mL.

There was no correlation between the farm prevalence of MUTD and the type of water nipple (p = 0.096) or the number of nest box water bottles used in relation to the total number of breeding females (p = 0.732).

Cage hygiene

Farms using short kit nets (n = 5) had significant higher prevalences of MUTD than farms using traditional long nets (p = 0.043). Farms that did not remove manure from the cage (n = 9) had significantly lower prevalence of MUTD than farms removing manure systematically or when needed (p = 0.031). Farms grouped by use of kit net disinfection (no use, used when needed, and systematically use) did not have significantly different prevalences of MUTD between groups (p = 0.203).

Microbial investigation

From 19 farms a total of 187 bladder swabs were sampled from mink with gross pathological lesions in the bladder. In 12 farms 10 animals were sampled. In the remaining farms between seven and 15 animals were sampled. The results are summarized in table 4.

	Bladder specimens	
Microbial culture findings	Pure culture (n)	Mixed culture (n)
Staphylococcus delphini group A	99	10
Proteus spp.	21	2
Proteus mirabilis	5	
Escherichia coli	4	1
Staphylococcus aureus	3	2
Other *Stapylococcus* spp.	5	5
Enterococcus faecalis		4
Pseudomonas spp.	1	1
Streptococcus canis	1	
Vagococcus fluvialis	1	1
Psychrobacter spp.	3	6
Micrococcus luteus		2
Candida famata		1
No match	5	13
Steril	18	
Total	166	48

Table 4: Microbial culture finding from bladder specimens collected from mink kits diagnosed with MUTD leading to mortality.

Swab specimens were collected from six animals with kidney lesions and the isolates were identified as *S. delphini* group *A* (n = 1), *Proteus spp*. (n = 3), *Staphylococcus pseudointermedius* (n = 1), and *Enterococcus faecalis* (n = 1).

Urolith analysis

The results of the urolith mineral analysis are shown in table 5. In 98 uroliths samples 70-100% of the nidus and/or (if nidus not present) body were composed of struvite. One sample had a nidus of 60% struvite and 40% ammonium urate with a body of 95% struvite and 5% ammonium urate (mixed urolith). Another had a nidus of 95% struvite and 5% ammonium urate with a body of 50% struvite and 50% ammonium urate (mixed urolith).

Crystal composition	Nidus (n)	Body (n)	Shell (n)	Surface (n)
No measurable components	90		95	100
100% struvite		62	2	
95% struvite, 5% carbonate-apatite	1	23	1	
90% struvite, 10% carbonate-apatite		7		
85% struvite, 15% carbonate-apatite	1	1	1	
80% struvite, 20% carbonate-apatite			1	
95% struvite, 5% ammonium urate	2	5		
85% struvite, 15% ammonium urate		1		
80% struvite, 20% ammonium urate	4			
70% struvite, 30% ammonium urate	1			
60% struvite, 40% ammonium urate	1			
50% struvite, 50% ammonium urate		1		
Total	100	100	100	100

Table 5: Results of quantitative mineral analysis of urolith samples from mink kits (n = 100).

Discussion

To our knowledge, this is the first study addressing the potential associations between MUTD in mink kits and management factors, though this disease has been recognized as an important production disease for many years. An exploratory study was conducted on 20 farms housing a total of 321.781 mink kits. MUTD were diagnosed postmortem in 851 mink kits. In figure 1 the prevalence of mink kits diagnosed with MUTD postmortem in July on 20 farms is presented. Farm 12 and 16 have noticeable higher prevalences than the remaining farms. With a sample of 20 farms the two farms with higher prevalence can have a high impact on the results of the statistical analysis. This is a clear limitation of our study and has been considered in the interpretation of the results.

The mean energy intake per female or female/litter each week from end of fetal implantation (week 15) throughout gestation, lactation and until July was recorded and analyzed for association with the prevalence of MUTD diagnosed postmortem in mink kits. Higher daily energy intake of females from 23rd to 29th of April (late gestation) was significantly associated with higher prevalence of MUTD ($p = 0.031$). The relation between feed intake of female mink during gestation and MUTD in mink kits in July is not clear. However, feeding in the last weeks of gestation has previously been related to other diseases including pre-weaning diarrhea in mink kits [17].

Daily energy intake in week 24 (10th-16th of June 2018) was significantly associated with lower prevalence of MUTD diagnosed postmortem ($p = 0.049$). Mink kits are born within a short period in the last week of April and first weeks of May [20]. Hence, week 24 is approximately six to seven weeks post parturition. In this period both the female and kits are eating the mink feed and drinking from the water supply, and the time spent suckling milk is reportedly sparse [21]. The period where the lactation is reduced and mink kits start supplementing the milk with feed and water is critical for the kits and sign of dehydration may be seen [21,22]. The feed consumption of lactating females increases with increasing milk production during lactation [23]. High feed consumption in females in June may reflect females with good milk production that could limit possible dehydration of kits in the transition from milk to feed. In addition, it seems reasonable that hydrated mink kits eat more feed than dehydrated mink kits, which would also increase feed consumption.

Shorter feeding intervals obtained by more frequent feedings in June were also related to a reduced risk of MUTD. This may be explained by additional water intake through moisture feed [24].

Higher proportion of breeding females in the color type black was significantly associated with higher farm prevalence of MUTD diagnosed post mortem in offspring. On the included farms 2.5% of the breeding females were of black color type (Table 2) and they were distributed on five farms. Farm 16 had the highest prevalence of MUTD. This farm exclusively bred black mink and contributed with 52% of all black breeding females of this investigation. Hence, the association found between black mink and MUTD occurrence is highly depended on this one farm, which should therefore be considered when interpreting the results. However, in another recent study of black mink the risk of post mortem diagnosis of MUTD was found to be higher in black mink compared to brown [25]. Further investigations are necessary to fully elucidate this potential genetic predisposition to MUTD in mink of black color type.

The results indicate that farms with heavy kits at the end of lactation (day 28 postpartum) have higher prevalence of mink urinary tract disease in July. However, farms with lower weight gain from day 28 to 95 post partum also have higher prevalence of MUTD. This may be due to the fact that fast growing mink kits with high body weight at the end of lactation do not gain as much weight during June and July as mink kits with low body weight at the end of lactation. In a previous study mink kits diagnosed postmortem with MUTD in July were found to have a significantly higher BMI and longer body length compared to mink kits dying of other causes [2]. It has been hypothesized that large male kits are in higher risk of urolithiasis because of high feed consumption and that rapid growth may predispose to infection by immune function impairment [2]. We could however not confirm an association between rapid growth during June and July and the prevalence of MUTD in this study. The number of litters included in weighing groups and kit loss from the first to the second weight recording varied greatly between farms. This is a clear limitation to our results.

In this study, urolithiasis was a frequent pathological finding in kits with urinary tract disease (Table 1). Low urine volume increases ion concentration and increases the risk of crystal precipitation [26,27]. Increased water intake can reduce precipitation risk by urine dilution [14]. It is documented that mink kits start drinking at an earlier age when water is available at the nest box [22]. The use of additional water though drinking bottles at the nest box was not found to be associated with mink urinary tract disease in this study. Other management factors can affect water availability and intake in mink kits, as feed moisture [24], placement of water nipple [22], and female lactation [23]. To investigate the potential effect of kit fluid intake on MUTD a more controlled study eliminating the effect of other farm factors should be effectuated.

The use of short kits nets was significantly associated with a higher farm prevalence of MUTD. The short nets reduce the amount of manure collected in the cage in front of the water nipple and improve hygiene in cage environment. Nine farms did not clean the inside of the cage during the lactation period, and they experienced a lower prevalence of MUTD compared to farms with cage cleaning procedures. This result is opposite of findings in sows where low hygiene was related to cystitis [28]. A possible explanation could be that the manure facilitates a bridge for mink kits to reach the water nipple (in height). It is possible that kits prefer walking on the fine meshed nets compared to the cage wire even if it is not clean. In that case, the short nets or removal of the nets would make it more difficult or less attractive to approach the water nipple at the far end of the cage.

Analysis of mink drinking water showed no association between water pH or total germ count and the prevalence of MUTD post mortem in mink kits, though farms receiving public water had significantly higher drinking water pH than farms using a private well. In humans, water with acidifying potential lowers urine pH [29]. In mink, drinking water with pH = 5.4 did not seem to affect urine pH compared to drinking water with pH = 8.5 [30].

Ammonium chloride is routinely used as a urine acidifier in farmed mink and has been shown to reduce mortality caused by MUTD in breeding female mink [12]. Only three farms did not use ammonium chloride during the study period. There was no association between ammonium chloride used as a feed additive on the prevalence of MUTD. This is in agreement with results of a recent study, where 3 ‰ ammonium chloride administration did not reduce mortality of MUTD compared to a control group (unpublished observations). Studies on mink kits have shown that feed supplement of ammonium chloride (3-3.5 ‰) significantly lowers urine pH [31]. While it does lower urine pH, it may not efficiently prevent development of MUTD and associated mortality.

Necropsy results of 851 mink kits with MUTD confirm previous reports of mucosal hemorrhage and edema of the urinary bladder, pyuria, hematuria and bladder obstruction being common pathological findings of MUTD [1,2]. Urolithiasis was diagnosed in 46% of kits with MUTD. In a previous study urolithiasis was diagnosed in 33% of MUTD cases diagnosed postmortem [2]. Our results confirms that more male mink kits (84%) are diagnosed with MUTD than females (16%) [2]. The increased risk of urethral obstruction in males has been suggested as a cause [1,2] and the high occurrence of obstruction (72%) registered in the present study is in agreement with this theory. Pyelonephritis was not a common finding in mink kits with urinary tract disease (8%).

S. delphini group A was identified as the main bacterial agent in 60% (99/166) pure cultures and 21% of mixed cultures (10/48) from mink kits diagnosed with MUTD in this study. This confirms previous identification of *S. delphini group A* as the main bacterial agent associated with MUTD [1,2]. *E. coli* is the most common pathogen cultured from urine of other carnivorous species as cats and dogs [32,33], though it does not seem to be a common pathogen in urinary tract disease in mink kits. *Proteus spp*. was detected in 16% (26/166) pure cultures and has also been found in bladder swaps from MUTD cases in previous investigations [1,34].

Struvite was the main mineral found in 98 mink urolith samples analyzed (n = 100) using standardized quantitative methods. The uroliths were collected from mink kits originating from 20 mink farms showing that struvite remains to be the main mineral in Danish mink uroliths in agreement with previous investigations [1,2]. Smaller quantities (5-20%) of carbonate-apatite (calcium phosphate carbonate) were also detected in either nidus, body, and/ or shell of some uroliths. Carbonate-apatite precipitates in alkaline pH and is a common finding in urease induced crystallization [35]. Carbonate-apatite is also reported the most common secondary mineral in feline struvite uroliths [36], though feline uroliths usually formats in sterile urine [7,36]. In this study, some uroliths also contained smaller amount of ammonium urate (5-30%). Two uroliths had over 30% ammonium urate in either nidus or body (mixed uroliths) [36]. Ammonium urate is also recognized in some feline struvite uroliths and in mixed stones with struvite [36].

Conclusion

MUTD associated with struvite urolith formation were identified as an important cause of mortality in post weaning mink kits at the farms included in this investigation. High feed energy intake in female mink and kits at the time of weaning and frequent feedings in June could be potential protective factors for MUTD, while short kit nets, and cage cleaning of manure could be potential risk factors. Feeding management at the time of weaning, mink kit growth, and cage hygiene is recommended as focus areas to be included in future studies of risk factors and preventive measures this important mink production disease. To investigate the effect of the potential risk factors on the development of MUTD and potential preventive measures further investigations are needed. The results of this exploratory observational study may contribute as basis for design of future studies.

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Author Contributions

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Institutional Review Board Statement

Ethical review and approval were waived for this study because it was an observational study only observing spontaneous disease occurrence (mortality) and no interventions nor handling of live animals took place. The animals were handled according to national legislation. No animals were culled for research purposes.

Data Availability Statement

The datasets of the current study are available from the corresponding author on reasonable request.

Conflict of Interest

None.

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