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Effect of Major Diseases on Productivity of a Large Dairy Farm in a Temperate Zone in Japan

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Abstract: The objective of the present study was to investigate the associations between major diseases (clinical mastitis, peracute mastitis, metabolic disorders, peripartum disorders) and four parameters related to productivity (305-day milk yield, number of days open, culling rate, death rate) on a large dairy farm in a temperate zone with approximately 2500 Holstein cows. Data were collected from 2014 to 2018 and involved 9663 calving records for 4256 cows. We found negative effects of clinical mastitis, peracute mastitis, metabolic disorders, and peripartum disorders on the productivity of cows. Clinical-mastitis-suffered cows with multiple diseases had more days open compared with those with clinical mastitis alone and the healthy group, and they had a higher death rate than the healthy group, whereas there was no difference in death rate between the clinical mastitis only and healthy groups. Cows suffering from peracute mastitis, metabolic disorders, and peripartum disorders with either single or multiple diseases exhibited reduced productivity compared with the healthy group. Our findings clearly show that major diseases of cows in a temperate zone have severely negative effects on their productivity.

Keywords: dairy cows; epidemiology; multiple disease; productivity; temperate zone

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1. Introduction

In order to reduce heat stress that decreased cow productivity, many dairy cattle farms are located in cold climate zones. Heat stress conditions decrease milk yield and fertility [1–3], but, to supply raw milk, there are several dairy farms in temperate zones. Our previous study conducted in temperate zones in Japan showed that cows under heat stress conditions decreased their productivities [4] and had a higher risk of major diseases such as clinical mastitis (CM), peracute mastitis (PM), metabolic disorders (MD), and peripartum disorders (PD) [5]. However, there is limited literature quantifying the effects of these diseases on the productivity of cows in temperate zones. In particular, identifying these effects should be conducted on large farms because large dairy farms have been recently increasing in number in Japan [6] and other countries such as United Kingdom [7], New Zealand [8], and USA [9], and large farms manage cows as groups and their herd management methods are different from those in small or middle farms. Additionally, the number of large dairy farms are increasing in China and Vietnam; these are located in temperate or tropical climate zones because of the huge increase in the demand for dairy products [10–12]. Thus, quantifying the effects of diseases on the productivity on large farms is essential to develop preventive measures as well as to minimize economic losses and predict reductions in the yield of dairy cows.

In general, the effects of diseases on productivity have been investigated using single disease status. CM is known to have negative effects on productivity [13–15], and some studies have shown that MD and PD also have negative effects on productivity [13,16,17]. However, previous studies discovered that the effect of disease on productivity differed between cows suffering from a single disease status and those suffering from multiple diseases status [18–21]. Only a few studies have focused on the effects of multiple diseases status on productivity even in cold climate zones, and no research has been conducted on the effects of multiple diseases in temperate zones.

In the present study, we aimed to assess the association between major diseases (CM, PM, MD, PD) of cows in a temperate zone and the productivity in cows raised on a large dairy farm in Japan.

2. Materials and Methods

2.1. Study Farm

The present study was conducted on a commercial dairy farm in an area with a temperate climate. The farm is located at 130°92′ E longitude and 33°29′ N latitude, and had approximately 2500 Holstein cows. The studied region had both cold winters and hot humid summers, and the average maximum temperatures in spring (Mar. to May), summer (Jun. to Aug.), autumn (Sep. to Nov.), and winter (Dec. to Feb.) on the studied farm were 22.1 °C, 31.6 °C, 23.8 °C, and 11.1 °C, respectively. In contrast, those in each season in Hokkaido, a major milk-producing region in Japan, were 10.5 °C, 21.2 °C, 14.8 °C, and 0.2 °C, respectively. The dairy cows studied were raised with free barn access and could lie on sawdust. Grazing for milking cows was not performed. As a breeding management, fixed-time artificial insemination was applied to all cows with the synchronization of estrus approximately 40–50 days after calving. If they failed to conceive, they reared with Japanese Black bulls and were impregnated via natural insemination. In order to alleviate herd stress, Internal Cooling Elements (Cargill Japan, Tokyo, Japan), sodium bicarbonate orally, and the use of fans and water sprays were performed in the summer season.

2.2. Data Collection

The present study used data on disease status, cow information, and productivity in the analysis. We extracted data for cows calved from 2014 to 2018 from 9663 electronic records that included cow information (identification number, birth date, and culling or death date), calving dates, 305-day milk yield, conception dates, and parity. Data for disease status were obtained from a clinical veterinary service section of the farm. For the 9663 calving records, the data files were checked for missing or invalid records. Records on the 305-day milk yield were only used for cows that produced milk for at least 100 days, and records were omitted from our analysis if the cow did not continue to produce milk for 100 days (1010 records of 305-day milk yield). Records of conception date for 2545 culled cows in the parity were omitted from our analysis. Missing data from 56 records of 305-day milk yield and 126 records of conception date were omitted from our analysis. The upper and lower 1% of records of 305-day milk yield and conception date were omitted from our analysis as outliers (171 milk records and 163 records of conception date). Hence, the study group comprised 9663 calving records, which included 8426 records on 305-day milk yield and 6829 records on conception date for 4256 animals. Animal Care and Use Committee approval was not obtained in this study because the data were collected from the database on the studied farm, and no experiments on live animals were performed.

2.3. Definition and Categorization

We measured cow productivity using the 305-day milk yield, number of days open, and culling rate. In addition, we measured the herd health using the death rate. The 305-day milk yield was defined as a cow's milk yield from day 1 to day 305 of the lactation period. If a cow did not produce milk for the entire 305 days, we estimated the 305-day milk yield following the formula provided by the Livestock Improvement Association of Japan.

Days open was defined as the number of days from calving to conception. Culling was defined for cows that were culled due to problems such as decreased milk yields or low reproductive performance. Death was defined for cows that had to be euthanized or certified as found dead on the farm by clinical veterinarians. We calculated the culling rate and death rate as the following formula:

$$\text{Culling (Death) rate (\%)} = \frac{\text{Number of cows culled (dead) in the parity}}{\text{Number of calvings}}.$$

Number of cows culled (dead) in the parity was defined as the number of cows that were culled or died in each parity, and number of calvings was defined as the number of calving in each group. We used the number of calvings as denominators because some animals had several calving records.

Disease status was defined for cows diagnosed and treated by the clinical veterinarians on the farm. The farm staff checked the cows' condition every morning, and clinical veterinarians diagnosed animals showing problems and treated those confirmed to be ill from the clinical signs and blood test results. We focused on major diseases highlighted by our previous study [13]: CM and PM were diagnosed within the parity, whereas MD and PD were diagnosed within 30 days of calving. Other diseases that were excluded from the analysis were enteritis, bloody milk, claw born lesions, and pneumonia.

We defined CM as follows: symptoms of mastitis, such as udder and milk problems, and a white blood cell count of more than 4000 cells/μL. Bacteria analyzed from cows with CM were mainly *Staphylococcus aureus* and *Streptococcus* sp. In addition, we defined PM as symptoms of mastitis, such as udder and milk problems, and a white blood cell count of less than 4000 cells/μL. The cows with PM were infected mainly with *Escherichia coli* and *Klebsiella* sp. MD included fatty liver, ketosis, and ketosis II, and PD included puerperal fever, retained placenta, lochia retention, and metritis.

Three clinical veterinarians worked on the studied farm, and they followed a standardized diagnostic protocol. If a cow had multiple disease types within the parity, the individual was counted multiple times. Cows diagnosed in a single time with only CM within the parity were defined as suffering from CM only. Similarly, cows diagnosed in a single time with only PM, MD, or PD within the parity were defined as suffering from PM only, MD only and PD only, respectively. Cows diagnosed multiple times with both CM and other diseases within the parity were defined as suffering from both CM and other diseases. Similarly, cows diagnosed multiple times with both PM and other diseases, both MD and other diseases, and both PD and other diseases within the parity were defined as suffering from both PM and other diseases, both MD and other diseases, and both PD and other diseases, respectively. Cows that had no diseases within the parity were allocated to the healthy group. For cows suffering from multiple diseases within the parity, we did not consider the order of disease in the parity. We compared the productivity of cows in the healthy group, cows suffering from single disease, and cows suffering from multiple diseases, and we evaluated each disease separately.

Calving months were categorized by season: winter (Dec. to Feb.), spring (Mar. to May), summer (Jun. to Aug.) or autumn (Sep. to Nov.). In addition, parity was classified as follows: 1, 2, 3, 4, or $\geq$5.

2.4. Statistical Analysis

We assessed the factors associated with 305-day milk yield or days open using a mixed-effects linear model and the factors associated with culling or death using a mixed-effects logistic regression model. The dependent variables were 305-day milk yield, days open, culling (whether a cow was culled [1 or 0] within each parity group), and death (whether a cow died [1 or 0] within each parity group). The independent variables were disease status group (healthy cows vs. cows suffering from CM, PM, MD, or PD only vs. cows suffering from both CM, PM, MD, or PD and other diseases), parity, and calving season. To normalize the distribution, a square root transformation for days open was applied, and the results were back-transformed. We evaluated each disease separately in the model. All possible two-way interactions between significant factors were included in all models, but insignificant interactions ($p > 0.05$) were removed from the final models. Regarding culling rate and death rate, we estimated the odds ratios and 95% confidence intervals if the effect was significant. Cows and calving year were included as random effects in terms of 305-day milk yield and days open, while culling rate and death rate included calving year as a random effect. p-values less than 0.05 were considered significant. All statistical analyses used in the present study were performed by using SAS software version 9.4 (SAS Institute Inc., Cary, NC, USA).

3. Results

In the present study, 9663 calving records for 4256 cows were used for the analysis. Of the 9663 calvings, 5146 (53.3%) were diagnosed and treated. Table 1 shows the number of diagnoses for each disease during the study period. For the 9663 calvings, the prevalences (the number of cows diagnosed for each disease divided by the number of calvings) of CM, PM, MD, and PD were 28.0%, 13.3%, 3.4%, and 3.7%, respectively.

Table 1. The number of diagnoses of each disease [1].

Disease Status	Calving Records
Clinical mastitis (CM)	
Cows suffered from CM alone	1546
Cows suffered from both CM and other diseases	1160
Peracute mastitis (PM)	
Cows suffered from PM alone	615
Cows suffered from both PM and other diseases	669
Metabolic disorder (MD)	
Cows suffered from MD alone	55
Cows suffered from both MD and other diseases	276
Peripartum disorder (PD)	
Cows suffered from PD alone	62
Cows suffered from both PD and other diseases	299

[1] Of the 9663 calving records, 5146 cows were diagnosed and treated, and 4517 cows were not diagnosed in the parity, the latter of which were allocated to the health group.

Regarding CM, the 305-day milk yield was associated with disease status, parity, and calving season (Tables 2 and 3; $p < 0.05$), and there was a significant interaction between disease status and parity (Table 4; $p < 0.05$). There were no differences in 305-day milk yield between the disease status for parity 1–4, whereas cows that suffered from both CM and other diseases had lower 305-day milk yields compared with those that suffered from CM only or healthy cows with parity ≥ 5 ($p < 0.05$). Days open was associated with disease status, parity, and calving season (Tables 2 and 3; $p < 0.05$), but there was no interaction between disease status and parity or calving season. Cows that suffered from both CM and other diseases spent more days open compared with those that suffered from CM only and those in the healthy group ($p < 0.05$). Culling rate was associated with disease status and parity ($p < 0.05$), but there was no interaction between disease status and parity. Cows having CM only or CM with other diseases had 2.56–4.06 higher odds of being culled compared with those in the healthy group ($p < 0.05$). Death rate was associated with disease status only, and cows that suffered from both CM and other diseases had 2.17 higher odds of mortality cows in the healthy group ($p < 0.05$).

For cows with PM, the 305-day milk yield was associated with disease status, parity, and calving season (Table 2; $p < 0.05$), and a significant interaction between disease status and parity ($p < 0.05$) was found. There were no differences in 305-day milk yield in parity 1–4 among the disease status, while those that suffered from both PM and other diseases had a lower 305-day milk yield than those that suffered from PM only or healthy animals with parity ≥ 5 ($p < 0.05$). Days open was associated with disease status, parity, and calving season ($p < 0.05$), but there was no interaction between disease status and parity or calving season. Cows having PM with or without other diseases had more days open compared with those in the healthy group ($p < 0.05$). Culling rate was associated with disease status and parity ($p < 0.05$), but there was no interaction between disease status and parity. Cows having PM with or without other diseases had 4.47–5.72 higher odds of being culled than healthy cows ($p < 0.05$). Death rate was only associated with disease status, and cows suffering from PM only had 5.33 higher odds of death compared with those in healthy group ($p < 0.05$).

Table 2. Comparison of productivity among disease status.

	305-Day Milk Yield, kg		Days Open, Day	
	N [1]	**Estimate ± SEM**	**N [1]**	**Estimate ± SEM**
Clinical mastitis (CM)				
CM alone	1386	9913 ± 198.5	1076	123.1 ± 3.5 b
CM and other diseases	1039	9798 ± 200.4	684	144.6 ± 3.8 a
Health	4218	9953 ± 196.2	3755	110.3 ± 3.0 c
Peracute mastitis (PM)				
PM alone	469	9801 ± 201.7	307	132.0 ± 4.5 a
PM and other diseases	610	9894 ± 201.1	373	139.4 ± 4.2 a
Health	4218	9967 ± 188.9	3755	110.6 ± 2.8 b
Metabolic disorder (MD)				
MD alone	14	8954 ± 452.8 b	11	103.5 ± 19.1 ab
MD and other diseases	118	9270 ± 258.5 b	77	134.8 ± 7.9 a
Health	4218	9958 ± 220.8 a	3755	110.9 ± 3.5 b
Peripartum disorder (PD)				
PD alone	33	9814 ± 342.2 ab	26	137.9 ± 15.9 ab
PD and other diseases	170	9375 ± 253.8 b	119	147.1 ± 6.8 a
Health	4218	9965 ± 230.0 a	3755	110.8 ± 3.6 b

	Culling rate, %			Death rate, %		
	N [1]	Mean	OR (95% CI [2])	N [1]	Mean	OR (95% CI [2])
Clinical mastitis (CM)						
CM alone	1546	28.0	2.56 (2.22–2.96)	1546	0.9	NS [3]
CM and other diseases	1160	38.3	4.06 (3.48–4.72)	1160	2.2	2.17 (1.33–3.56)
Health	4517	13.0	Reference	4517	1.2	Reference
Peracute mastitis (PM)						
PM alone	615	48.1	5.72 (4.75–6.89)	615	5.7	5.33 (3.37–8.44)
PM and other diseases	669	42.2	4.47 (3.72–5.37)	669	1.9	NS [3]
Health	4517	13.0	Reference	4517	1.2	Reference
Metabolic disorder (MD)						
MD alone	55	78.2	20.42 (10.57–39.47)	55	1.8	NS [3]
MD and other diseases	276	71.7	15.09 (11.36–20.04)	276	2.9	2.31 (1.06–5.05)
Health	4517	13.0	Reference	4517	1.2	Reference
Peripartum disorder (PD)						
PD alone	62	54.8	9.57 (5.68–16.15)	62	4.8	4.03 (1.20–13.51)
PD and other diseases	299	58.5	9.01 (7.00–11.58)	299	3.0	2.62 (1.26–5.42)
Health	4517	13.0	Reference	4517	1.2	Reference

Values without the same letters (a, b, c) within a column differed significantly ($p < 0.05$); [1] Number of calving records; [2] OR (95% CI): odds ratio (95% confidence interval); [3] NS: not significant.

For MD, there was a relationship between the 305-day milk yield, disease status, parity, and calving season (Table 2; $p < 0.05$), but there was no interaction between disease status and parity or calving season. Cows with MD, regardless of the absence or presence of other diseases, showed a reduction in the 305-day milk yield compared with cows in the healthy group ($p < 0.05$). We found an association between days open and disease status, parity, and calving season ($p < 0.05$), but there was no interaction between disease status and parity or calving season. Cows suffering from both MD and other diseases had more days open compared with those in the healthy group ($p < 0.05$). Culling rate was associated with disease status and parity ($p < 0.05$), but we found no interaction between disease status and parity. Cows having MD, with or without other diseases, had 15.09–20.42 higher odds of being culled compared with healthy animals ($p < 0.05$). Death rate was only associated with disease status, and cows with both MD and other diseases had 2.31 higher odds of mortality than those in the healthy group ($p < 0.05$).

Table 3. Comparison of productivity by parity or calving season (model: clinical mastitis).

	305-Day Milk Yield, kg			**Days Open, Day**		
	N [1]	**Estimate ± SEM**		**N [1]**	**Estimate ± SEM**	
Parity						
1	1498	8189 ± 38.6 d		1339	106.9 ± 1.8 b	
2	1874	9718 ± 45.4 c		1547	119.6 ± 1.8 a	
3	1441	10,342 ± 52.1 b		1175	119.2 ± 2.0 a	
4	871	10,909 ± 59.9 a		699	118.4 ± 2.5 a	
≥5	959	10,669 ± 59.0 a		755	116.4 ± 2.2 a	
Calving season [3]						
Spring	1543	9357 ± 50.0 c		1298	125.1 ± 2.1 a	
Summer	1629	9527 ± 50.1 c		1381	119.6 ± 1.8 b	
Autumn	1837	10,025 ± 49.7 b		1531	107.8 ± 1.6 c	
Winter	1634	10,245 ± 49.2 a		1305	112.0 ± 1.9 c	
	Culling rate, %			Death rate, %		
	N [1]	Mean	OR (95% CI [2])	N [1]	Mean	OR (95% CI [2])
Parity						
1	1660	15.1	Reference	1660	1.4	NS [4]
2	1960	17.1	NS [4]	1960	1.1	
3	1565	22.9	1.33 (1.10–1.61)	1565	1.2	
4	969	25.3	1.58 (1.28–1.95)	969	0.9	
≥5	1069	25.6	1.57 (1.27–1.93)	1069	2.2	
Calving season [3]						
Spring	1650	18.5	NS [4]	1650	1.0	NS [4]
Summer	1798	20.5		1798	1.3	
Autumn	2007	19.9		2007	1.6	
Winter	1768	22.1		1768	1.2	

Values without the same letters (a, b, c) within a column differed significantly ($p < 0.05$); [1] Number of calving records; [2] OR (95% CI): odds ratio (95% confidence interval); [3] Calving season: Spring (March–May), Summer (June–August), Autumn (September–November), and Winter (December–February).; [4] NS: not significant.

Table 4. Multivariable models comparing 305-day milk yield to clinical mastitis (CM) status and parity.

Parity	**Disease Status**					
	Health		**CM Alone**		**CM and Other Diseases**	
	N [1]	**Estimate ± SEM**	**N [1]**	**Estimate ± SEM**	**N [1]**	**Estimate ± SEM**
1	1199	7704 ± 199.2 d	192	7769 ± 221.0 d	107	8014 ± 244.0 c
2	1216	9626 ± 198.7 c	389	9779 ± 207.1 c	269	9741 ± 213.6 b
3	796	10,473 ± 201.2 b	354	10,433 ± 207.9 b	291	10,240 ± 210.5 a
4	490	10,880 ± 205.1 a	221	10,722 ± 214.4 ab	160	10,661 ± 222.8 a
≥5	517	11,082 ± 206.3 ax	230	10,860 ± 216.3 ax	212	10,334 ± 217.8 ay

Values without the same letters (a, b, c, d) within a column differed significantly ($p < 0.05$); Values without the same letters (x, y) within a row differed significantly ($p < 0.05$); [1] Number of calving records.

In animals diagnosed with PD, we found that the 305-day milk yield was related to disease status, parity, and calving season (Table 2; $p < 0.05$), but there was no interaction between disease status and parity or calving season. Compared with those in healthy group, cows suffering from both PD and other diseases had a lower 305-day milk yield ($p < 0.05$). Days open was associated with disease status, parity, and calving season ($p < 0.05$), but there was no interaction between disease status and parity or calving season. Cows that were diagnosed with both PD and other diseases had more days open compared with those in the healthy group ($p < 0.05$). Culling rate was associated with disease status and parity ($p < 0.05$), but there was no interaction between disease status and parity. Death rate was associated only with disease status. Cows diagnosed with PD, regardless of the presence or absence of other conditions, showed 9.01–9.57 higher odds of being culled and 2.62–4.03 higher odds of death compared with healthy animals ($p < 0.05$).

4. Discussion

The present study quantified the effect of major diseases on productivity such as 305-milk yield, days open, culling rate, and death rate on a large Japanese dairy farm located in a temperate climate zone. Although negative effects of major diseases on the productivity in the present study agrees with previous studies conducted in cold zones [17,21–23], our findings showing few interactions between disease status and calving season on productivity indicate that the negative effects of major diseases on productivity were independent of heat stress. Additionally, our results quantifying the effect of diseases on productivity on a large dairy farm, and those of our previous study investigating the prevalence and incidence rates of each disease on a large dairy farm [5], can be used to predict long-term herd productivity and help to ensure appropriate culling guidelines and practice are implemented on large dairy farms.

Our results suggested that CM had few effects on productivity, and cows suffering from CM showed reduced productivity only when they concurrently suffered from other diseases. A previous study conducted in a cold area showed that reproduction was affected to a greater extent in cows with both mastitis and other diseases than in those with a single disease [18]. In addition, mastitis has been said to increase the risk of subsequent disorders [24]. It is recommended that producers intensively care for cows suffering from CM to prevent them from contracting other diseases. In contrast, there was no reduction in the 305-milk yield of cows with CM compared with that of healthy cows, regardless of the presence of other diseases, except for those in parity $\geq$5, which disagrees with previous studies reporting the negative effects of CM on milk yield [13–15]. A possible reason for this is that some cows diagnosed from CM had a higher 305-milk yield. Higher-producing cows are at a greater risk for CM [25], and the farm at which our study could not regulate the amount of feed given to high-milk yielding cows because they managed as a group; this may have caused the discrepancies between our results and those of previous studies. Intensive care for higher-producing cows on large dairy farms might minimize the loss of productivity caused by the occurrence of CM.

Regarding PM, we found that cows that suffered from only PM had >20 more days open and a 4.5% higher death rate compared with healthy cows. However, there was no difference in the death rate between cows suffering from both PM and other diseases and those in the healthy group. These results indicate that PM alone may have significant impact on productivity, and some cows with PM alone were dead because of its severity. Previous reports showed that, because of disease severity, mastitis caused by *Escherichia coli* and *Klebsiella* sp. harms the productivity and welfare of dairy cows [26,27]. It is important to provide intensive care to cows diagnosed with PM, regardless of the presence or absence of other diseases, to minimize economic loss caused by livestock deaths.

In the present study, approximately 80% of cows showing a metabolic or peripartum disorder suffered from other diseases, indicating that animals with MD or PD had a higher risk of having other diseases involved. It is noteworthy that this resulted in a lower number of MD and PD alone, which may affect the reliability of relevant analysis. Additionally, cows suffering from MD, either with or without other diseases, had a serious loss of productivity compared with those in the healthy group. These results indicate that metabolic and peripartum disorders have significant impacts on productivity, despite disease status (whether PM is accompanied with other diseases), on large dairy farms located in temperate climate zones in Japan. Previous reports conducted in cold climate zones showed that cows suffering from either metritis or ketosis only and those with metritis or ketosis in combination with other diseases had decreased milk yields and fertility, an increased chance of culling, and a higher proportion of deaths [19–21]. It is important to identify sick individuals and treat them immediately so that they do not suffer from these diseases. Furthermore, the higher culling rate found in cows suffering from metabolic disorders and the higher death rate found in those suffering from peripartum disorders might be associated with economic losses and animal well-being concerns. Thus, it is important for producers to minimize the risk of metabolic disorders by using feeding management programs to retain the animals' energy balance, to take particular care around calving, and to prevent the occurrence of peripartum disorders by predicting the timing of calving or conducting suitable calving assistance.

The culling rate in our study was 26.3%, which is comparable to the rates in previous reports [28–32]. Additionally, the culling rate was associated with the occurrence of each disease or parity, but there was no interaction between these factors. The most common reasons for culling are the occurrence of mastitis, a reduction in milk yield, and high parity [33], but few studies have investigated the interactions among these factors. It is important to provide intensive care to sick cows, regardless of their parity or calving season. The death rate in our study was 2.2%, which is lower than that found in a previous study conducted in a cold zone [34], indicating that the occurrence of death in temperate zones can be minimized by adopting good management procedures. Large dairy farms are likely to pay more attention to cow health and strengthen monitoring [12], which may have caused the reduction of the death rate on the farm at which our study was conducted. In the present study, however, we did not consider the effects of culling season or death season, and further studies are needed to confirm the effects of these factors on culling and death rates. In addition, the standards of culling may be different among farms, and further research and analysis are required to identify this point.

A limitation of the present study was the lack of information on nutritional condition and management issues, and this may have affected the disease status or productivity. Additionally, the present study was not a controlled experiment, but an observational study using records from a commercial farm. Thus, the findings should be interpreted only as an association, not as indicators of biological causation. Furthermore, we collected data from one farm, and our findings cannot be generalized to the entire farms that were located in the temperate zone of Japan. Even with these limitations, the present study clarified the effects of CM, PM, MD, and PD on cow productivity in a temperate zone in Japan.

5. Conclusions

This study showed that certain important diseases of cows had negative effects on dairy productivity on large farms in a temperate zone, and the effects of the major diseases on productivity were independent of other factors analyzed. In addition, CM had few effects on productivity, whereas PM, MD, and PD had serious negative effects on productivity on large farms in a temperate zone. Therefore, it is important to prevent cows contracting PM, MD, and PD in order to minimize the loss of productivity.

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Data Availability Statement: The data presented in this study are available upon request from the corresponding author. The data are not publicly available due to privacy.

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Conflicts of Interest: T.M., K.H. and Y.H. are from Honkawa Ranch. And they are involved in experimental design, and this company only provide clinical documents on subjected cows for this project.

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