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Effect of Non-Genetic Factors on Reproductive and Productive Traits of Crossbred Murrah Buffaloes

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Abstract
Background: Buffaloes, integral to rural Nepal, significantly impact agricultural productivity and community socio-economic well-being. Strategic breeding initiatives and effective management practices enhance buffalo farming efficiency. Evaluating milk yield and reproductive traits in crossbred Murrah buffaloes allows us to identify superior individuals. However, there is a trade-off between milk yield and reproductive characteristics. Climate, genotype, nutrition, and herd management influence these traits, helping us identify genetically superior buffaloes. This research aims to assess non-genetic factors' impact on crossbred Murrah buffalo traits, optimizing productivity interventions and breeding calendars.
Materials and Methods*: The performance records of 16912 buffaloes from the year 2017 to 2020 at mid-hill and Terai and maintained at the Veterinary Hospital Livestock Specialties Center, Artificial Insemination records, buffalo farm were used for analysis. We analyzed the data by using the mixed technique of the Harvey model.*
Results: *The analysis revealed that the overall least squares mean for body weight (BW), age at conception (AC), age at first calving (AFC), Calving interval (CI), length of lactation (LL), lactation milk yield (LMY), standard milk yield (SMY), and daily milk yield (DMY), Peak milk yield (PMY), was found to be 35.10±0.56 kg, 975.14± 10.54 days, 1287.88± 10.50 days, 420.00± 3.60 days, 276.66± 2.32 days, 2097.64±39.88 lit., 2310.59±37.29 lit., 7.5±0.012 lit., and 9.76±0.015 lit., respectively. The study found significant differences ($p<0.01$) in buffalo calves' weight throughout birth seasons, with winter having the highest weight. Location, period, season, and parity significantly influenced ($p<0.001$) age at conception, age at first calving, and calving interval.*
Conclusion: *The research findings underscore the non-genetic factors significantly influence reproductive and productive traits of crossbred Murrah buffalo, requiring the execution of improved breeding management and selection of superior buffaloes in different domains of Nepal.*
Keywords: *Crossbred Murrah Buffalo, Non-genetic factors, Production traits, Reproduction traits*

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I. Introduction

Buffaloes are significant in global agriculture since they offer milk, meat, and draft power to millions of people, particularly in developing countries[1]. Buffaloes, especially crossbred Murrah buffaloes, are important for meeting the dairy needs of rural communities in Nepal, where agriculture is a key part of the economy[2]. Nepal's gross domestic product (GDP) is derived from agriculture, which employs 66% of the population. Livestock accounts for 12% of GDP, with buffaloes accounting for 6% of the total[3]. Further, they state that the buffalo population of Nepal is 52.5 million, contributing to an annual milk production of 1.4 million MT and meat production of 0.19 million MT, which accounts for 57% of milk and 36% of meat production. Although, Murrah buffalo is the highest milk producing and their production and reproduction efficiency varied under different management conditions[4]. The Nepalese rural farmers face the issues of crossbred and Murrah buffaloes having delayed puberty, seasonal breeding, and, ultimately, low productivity. The study behind these reasons is highly relevant for genetic improvement, management practices, and policy decisions, and buffaloes are a significant source of milk and meat in Nepal[5].In Nepal 35% of the population consists of exotic Murrah buffaloes, with the remaining 65% being indigenous[6].

Crossbred Murrah buffaloes commonly inhabit low hills and Terai regions, especially in areas with milk marketing potential. While indigenous buffalo breeds generally have lower milk productivity, averaging 2.85 liters per animal per day, the Murrah buffalo can produce 1500 liters of milk per lactation period under

similar management conditions[7]. Nonetheless, insufficient consideration of non-genetic factors affecting Murrah buffalo traits is hindering productivity improvements. Factors such as climate, genotype, nutrition, and herd management practices all influence the reproductive traits of buffaloes and can be utilized to identify genetically superior animals. We have selected this research to evaluate the non-genetic factors' effect on reproductive and productive traits of crossbred Murrah buffalo in different domains, optimizing productivity interventions and breeding schedules.

II. Material And Methods

Study Area

This research was done in Terai of Dhanusha and the Hill of Kaski districts, Nepal. The district lies at an altitude ranging from 78 meters of terai and 450 to 3937 meters of mid-hill above sea level of Dhanusha and Kaski, respectively. Dhanusa District belongs to the Madhesh Province, Nepal at latitude 2650′31.56″North, longitude 8602′09.60″E and Kaski of mid-hill at latitude 28.2622 N longitude 84.0167 E.

The Terai is hot summers and moderate winters, often reaching highs of above 40^{c}.The region boasts a subtropical climate. Winters are milder, with temperatures ranging from 7^{0}C to 23^{0}C, and precipitation ranging from 1500 mm to 3000 mm. With annual rainfall ranging from 1500 mm to 2500 mm and temperatures fluctuating between 15^{0}C and 25^{0}C, the mid-hill region enjoys a temperate environment characterized by distinct seasons.

Study location and the duration

The data on economic traits of crossbred Murrah buffaloes were collected from animal breeding record sheet of buffaloes for the period of 2017 to 2020 maintained at the Veterinary Hospital & Livestock Specialties Center, and buffaloes rearing farmers of different rural municipality in in Terai, and hill of Nepal.

Production system information

We created a questionnaire and asked people in two different regions, Terai and Hill, to answer it verbally. The study encompassed crossbred Murrah buffaloes from these two locations, totaling 16,912 animals. We gathered information on reproductive and productive traits from 16,912 lactating buffaloes. Performance records of 10,987 buffaloes were sourced from the Veterinary Hospital & Livestock Specialties Center in Terai, while 5,925 were obtained from various rural municipality in the hill district. Data collection included information on all buffaloes born and calved at the farm, with a focus on those rearing between one and up to 100 milking buffaloes over a period of three years.

Herd management

Buffaloes were housed on large farms, with a minimum of one to 100 animals. They grazed on grasses for 4 to 6 hours daily, receiving commercial concentrates and roughages twice daily. Feed varied based on the animal's condition, with a chemical composition of 16% crude protein, 3% fat, 10-12% crude fiber, and 12% moisture content. Water was available, and female buffaloes were artificially inseminated during estrus.

Agro-climatic seasons

The year was stated based on the availability of agro-climatic conditions namely, summer (June to August), autumn (September to November), winter (December to February), and spring (March to May). The farm experiences each of the four seasons all year long. First and second lactation were considered as early parity, third and fourth lactation as mid parity, and five and above considered as late parity.

Statistical analysis

We entered all the collected data in MS Excel on various sheets and performed data cleaning to make it easily readable. We also used R software to analyze the data using animal models, specifically Harvey's Henderson Least Squares and Maximum Likelihood (LSMMML PC-2)[8]. The model analyzed the effects of parity, location, and season on reproductive and productive attributes.

$$Yijk = \mu + Bi + Pj + (BP)ij + eijk$$

Where,

Yijk is the observation on the kth parity of ith breed;
μ is the overall mean;
Bi is the fixed effect of *ith* breed of buffalo;
Pj is the fixed effect of *jth* parity;
(BP) ij is the effect of interaction between *ith* breed and *jth* parity; and
eijk is the random error that is assumed to be normally and independently distributed (NID).

III. Results

The chapters covenants with the finding of a detailed study about the economic traits of crossbred Murrah buffaloes. The economic traits denotes the reproductive, productive, and milk constituents, respectively.

Reproduction Traits and their findings

Age at Conception

The results of this study revealed that the overall mean age at conception of buffalo was 975.14± 10.54 days (Table 1).The study revealed notable variations in the age at conception of crossbred Murrah buffalo across different locations, seasons, and parities. The Terai region showed a 24.75% higher age at conception compared to the Hill region. Additionally, the age at conception varied significantly across different time periods and seasons, with the highest mean in summer and the lowest in spring. Parity also had a significant effect, with the lowest mean observed in the 2nd parity and the highest in the 3rd during spring.

Age at first calving

The overall mean age of first calving was 1287.88±10.50 days observed on crossbred Murrah buffalo (Table 1 & Fig 1). The results indicate a noteworthy difference in the age at first calving between the Terai region and the Hill region, with the Terai region exhibiting a significantly longer duration (1385.53 days, $p<0.001$) compared to the Hill region (1284.54 days). The year influenced this trait, with 2020 showing a higher age at first calving (1285.24 ± 10.53 days). The age at first calving differed across seasons: summer (1296.54 ± 10.59 days), autumn (1282.41 ± 10.51 days), winter (1282.41 ± 10.51 days), and spring (1282.41 ± 10.50 days). The least-square means for the first, second, and third parity were 1318.35 ± 0.89 days, 1317.97 ± 0.97 days, and 1322.05 ± 1.06 days, respectively.

Table 1. Least Square Means and standard error for reproductive traits

Factors	N	AC (days)	AFC (days)	GL (days)	CI (days)
Overall	μ16912	975.14± 10.54	1287.88± 10.50	312.72± 0.41	420.00± 3.60
Location					
Significance		P<0.001	P<0.001	P<0.001	P<0.001
Terai	10987	1291.22± 10.52	1385.53± 10.52	312.62± 0 .41	422.34± 3.61
Hill	5925	971.70± 10.55	1284.54± 10.51	312.83± 0.41	417.65± 3.61
Period					
Significance		P<0.001	P<0.001	P<0.001	P<0.001
2018	4404	972.47±10.57	1285.24±10.53	312.76 ±0.41	423.93± 3.61
2019	5117	971.97 ±10.57	1284.79±10.53	312.81±0.41	420.61±3.61
2020	7391	980.99±10.57	1293.61±10.52	312.60±0.41	415.45±3.61
Season					
Significance		P<0.001	P<0.001	P<0.001	P<0.001
Summer	1964	983.77± 10.63	1296.54±10.59	312.73± 0.41	419.90± 3.63
Autumn	8316	969.41± 10.56	1296.54±10.59	313.00±0.41	420.25±3.61
Winter	5315	973.75±10.56	1282.41± 10.51	312.73± 0.41	417.29± 3.61
Spring	1317	973.65±10.67	1286.09± 10.63	312.44±0.39	422.55±3.65
Parity					
Significance		P<0.001	P<0.001	P<0.001	P<0.001
First	6867	1006.06±0.89	1318.35± 0.89	312.26±0.35	391.41±0.44
Second	5709	1005.71±0.98	1317.97± 0.97	312.28± 0.38	396.83± 0.43
Third	4330	1009.76±1.06	1322.05± 1.06	312.26± 0.41	395.99± 0.43
CV		6.41	4.87	0.81	5.26
R2		0.013	0.012	0. 007	0. 041

Where significant at *P<0.01, ACO (Age at conception), AFC (Age of first calving), GL (Gestation length), CL (Calving length)

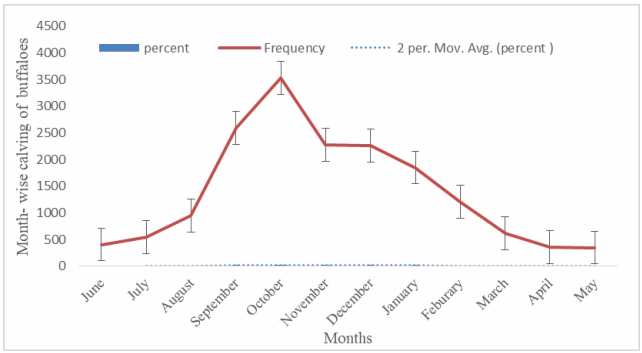

Fig.1. Status of monthly calving of crossbred Murrah buffaloes in Nepal

Gestation Length

The overall mean gestation length was 312.72±0.41 days (Table 1).The study found that location significantly impacts the gestation length of crossbred Murrah buffaloes, with the hill region having a slightly higher gestation length. The year significantly impacts gestation length, with 2019 having a higher length of 312.81±0.41 days. Seasons have a significant effect on gestation length, with the highest mean observed in autumn and the lowest in winter. Parity of the buffalo plays a role, with the least square mean of gestation length in the 1st, 2nd, and 3rd parities being the highest, with the lowest in the other two parity.

Calving interval

The research findings indicated that the calving interval for crossbred Murrah buffaloes was longer in the Terai region compared to the Hill region, and there were significant variations between the two regions. The study also highlighted the influence of the year on the calving interval, with 2018 showing a notably longer interval of 423.93±3.61 days. Furthermore, the seasons were found to have a significant impact on the calving interval, with the longest interval occurring in spring and the shortest in winter. Additionally, the calving interval varied significantly based on parity (Table 1).

Productive traits and their findings

Lactation length

The overall least squares mean of lactation length (LL) of crossbred Murrah buffaloes in this study was 276.66± 2.32 days (Table 2). The study revealed that the location had a significant impact on buffalo lactation length. The Terai region had the longest lactation period at 278.50 days, with the shortest being observed in another mid-hill region at 274.82 days. The year of calving did not have a significant effect on lactation length, but 2019 showed a longer average duration at 277.95±2.33 days, followed by 2020 at 276.51±2.33 days, and 2018 at 275.52±2.33 days. Furthermore, the season significantly affected the length of lactation, with summer having the longest duration at 273.33±2.34 days, followed by autumn at 279.41±2.32 days, and winter at 28.12±2.32 days. The lactation length of 1st, 2nd, and 3rd parity was 391.41±0.44 days, 396.83± 0.43 days, and 395.99±0.43 days, respectively. Lactation length had a significant influence ($p<0.001$) on different parity.

Lactation milk yield

The results of this study reflect the overall mean of lactation milk yield of crossbred Murrah buffaloes as 2097.64±39.88 liters (Table 2). The study highlighted the significant impact of lactation milk yield on Murrah buffaloes in the Terai and hill regions. Buffaloes in the Terai region demonstrated a 5.26 percent increase in milk yield compared to those in the hill regions. Notably, buffaloes calving in 2018 and 2019 showed longer lactation milk yield values, while winter emerged as the most productive season for milk yield. The study also emphasized that the first parity exhibited the highest yield, with the optimal lactation milk yield found in the second parity.

Table 2. Least Square Means and standard error for productive traits

Factors	N	LL (days)	LMY (lit)	SMY (lit)	DMY (lit)	PMY (lit)
Overall μ	16912	276.66± 2.32	2097.64±39.88	2310.59±37.29	7.5±0.012	9.76±0.015
Location						
Significance		p<0.001	p<0.001	p<0.001	p<0.001	p<0.001
Dhanusa	10987	274.82± 2.33	2154.37± 39.95	2388.68± 37.36	7.83± 0.04	10.15± 0.16
Kaski	5925	278.50± 2.32	2040.92± 39.90	2232.49± 37.32	7.3± 0.01	9.37± 0.016
Period						
Significance		p<0.001	p<0.001	p<0.001	p<0.001	p<0.001
2018	4404	275.52±2.33	2133.57±39.97	2360.39±37.38	7.73±0.001	10.07±0.001

2019	5117	277.95±2.33	2078.00±39.98	2277.29±37.39	7.46±0.001	9.71±0.001
2020	7391	276.51±2.33	2081.36±39.96	2294.08±37.36	7.46±0.001	9.49±0.001
Season						
Significance	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	
Summer	1964	273.33± 2.34	2096.40± 40.19	2338.83± 37.59	7.43±0.01	9.94± 0.016
Autumn	8316	279.41±2.32	2154.03±39.94	2348.66±37.36	7.49± 0.01	9.97±0.016
Winter	5315	278.12±2.32	2088.06± 39.92	2286.39± 37.33	7.70±0.01	9.60± 0.016
Spring	1317	275.78±2.35	2052.08±40.34	2268.48±37.73	7.66± 0.07	9.53±0.016
Parity						
Significance	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	
First	6867	279.73± 0.19	2175.50±3.38	2371.87±3.16	7.77±0 .01	9.98±0 .08
Second	5709	279.48± 0.21	2179.72± 3.71	2378.26± 3.46	7.79± 0.01	9.41± 0.014
Third	4330	278.99± 0.23	2161.58± 4.02	2361.84± 3.76	7.74± 0.01	9.93± 0.016
CV	4.86	11.05	9.50	9.51	9.68	
R^2		0.001	0.078	0.128	0.127	0.196

Where significant at *p<0.05: LL (lactation length), LMY (lactation milk yield), SMY (standard milk yield), DMY (daily milk yield), and PMY (Peak milk yield)

Standard milk yield

The findings of the study indicate that crossbred Murrah buffaloes have an average standard milk yield of 2310.59 ± 37.29 liters (Table 2). The location, specifically the Terai and Hill regions, significantly influenced the standard milk yield, with the Terai region exhibiting a 6.50% increase compared to the Hill regions. Additionally, the year had a notable impact on the standard milk yield, with higher values observed in 2018 and 2020. Seasonal variations were evident, with the highest standard milk yield recorded in winter (2348.66 ± 37.36 liters), followed by spring (2338.83 ± 37.59 liters), autumn (2286.39 ± 37.33 liters), and summer (2268.48 ± 37.73 liters). Furthermore, the study noted that the second parity achieved the highest standard milk yield.

Daily milk yield

The results of this study observed the overall least squares mean of daily milk yield at 7.5±0.012 liters (Table 2). According to the study, crossbred Murrah buffaloes in Terai produced 6.75% more daily milk yield compared to those in mid-hill Nepal. The study revealed that the year and season had significant effects on daily milk yield, with Terai experiencing longer values and seasonal variations affecting the yield. Specifically, the study found that summer yielded 7.43±0.01 liters, autumn 7.49±0.01 liters, winter 7.70±0.01 liters, and spring 7.66±0.07 liters. Likewise, the daily milk yield in the 1st, 2nd, and 3rd parity was significantly different, with the 2nd parity producing the highest amount of milk.

Peak milk yield

The study found that the peak milk yield for crossbred Murrah buffaloes was 9.76±0.015 liters (Table 2). In the Terai and hill regions, the peak milk yield was 7.83±0.04 and 7.3±0.01 liters, respectively, showing a 6.7% increase in the Terai. The year had a significant impact on the peak milk yield, with a higher value of 10.07±0.001 in 2018. Peak milk yield also varied significantly with the season, with higher average yields in winter and spring. Peak milk yield for the 1st, 2nd, and 3rd parity was 9.98±0.08 liters, 9.41± 0.014 liters, and 9.93± 0.016 liters, respectively, with the 1st parity showing the optimum peak milk yield.

IV. Discussion

In this study, we aimed to explore the non-genetic effect on reproductive traits, and productive traits on crossbred Murrah buffaloes, focusing on the impact of milk constituents' fat, protein, and lactose content on productivity.

Reproduction Traits and their findings

Effect on Age at Conception

The overall mean age at conception for crossbred Murrah buffaloes, as determined by our data, was 975.14 ± 10.54 days. The age at first conception for crossbred Murrah buffaloes was 2.9 ± 0.7 years greater than the age at conception in our current study[9] (Table 1). Genetics, a healthy diet, stress, and environment are primary factors influencing puberty onset, with hormones, particularly gonadotropins and sex steroids, playing a crucial role[10]. River buffaloes typically reach puberty between the ages of 15 and 18 months, while swamp buffaloes reach puberty between the ages of 21 and 24 months[11].

Effect on Age at calving

The range of the average age at first calving in Murrah buffalo has been documented and it is significantly higher than present results (Table 1), ranging from 1307.18 ± 12.39 days to 1578.7 ± 20.3 days[12, and 13], respectively. The age at first calving can be reduced through proper nutritional and health management of growing heifers[14]. The decrease in AFC resulting in a decrease in the cost of raising the animals to reach a productive life and an increase in the annual genetic gain[15].

Effect on Gestation length

The average gestation length of Graded Murrah buffaloes maintained under field conditions in India was 308.68 ± 0.27 days[16] and it is comparatively higher in present study. The average gestation length of crossbred, Nilli Ravi, and Murrah buffalo in the Bangladesh was revealed that 313.40 ± 4.97, 313.65 ± 5.16, and 311.59 ± 6.17 days, respectively, aligning with our finding[17] (Table 1). The importance of temperature, humidity, and seasonal variation with combined effect of proper nutrition and management practices to maintain gestation length of buffaloes [18, 19].

Effect on Calving interval

Our findings supports the study concerning the duration of calving intervals in crossbred Murrah buffaloes[20] (Table 1). Our study confirms that a combination of genetic, non-genetic, and environmental factors influences the calving interval in these buffaloes[21]. The availability of quality fodder and nutrition, regular health service can help to minimize the calving intervals in well-nourished buffaloes[22]. This study found that crossbred Murrah buffaloes have moderate variability in reproductive traits, with the lowest CV observed for conception and gestation period. This suggests that implementing selection strategies and improved management practices could improve these traits.

Productive traits and their findings

Effect on Lactation length

In our study, the observed overall LSM for lactation length (Table 2) was in contrast with finding [23], who observed that the LSM for LL of 340.48±14.14 days, LSM for LMY of 2465.48±130.72 kg, LSM for SMY of 2258.17±95.73kg, LSM for PMY of 13.17±0.45 kg and similar to the LSM for DMY of 7.66±0.01 kg, respectively. This finding revealed that parity plays a significant role in determining the duration of lactation in crossbred Murrah buffaloes. Additionally, researcher found factors influenced that lactation length, such as the year of calving, dry period, sex of the calf, and season of calving in water buffaloes[24].

Effect on Lactation milk yield

The findings revealed that the mean lactation milk yield was 1838.45±32.33 kg (1783.30L) [25], significantly lower than the lactation milk yield of crossbred Murrah buffaloes in our study, (Table 2). In their study, researchers reported a lactation milk yield of 1726.11 ± 45.89 liters in crossbred Murrah buffaloes[26]. Murrah buffaloes in Haryana had a total lactation yield as high as 2486 L in fourth parity and as low as 2061 L in the sixth parity[27]. Higher values of lactation milk yield in Murrah Buffalo was reported to be 2260±701 kg[28]. Furthermore, buffaloes that calved in the autumn season are less influenced by heat stress during lactation, exhibiting the highest lactation milk yield, followed by those calving in summer and winter[29], contrasts with our findings.

Estimation of Genetic Parameters for Productive Traits of Murrah Buffaloes in Kaski, Nepal

Effect on Standard milk yield

Researcher found that the a high yield in the second parity (2301 liters) while the low yield in the fifth-sixth parity (1176 liters) over the standard 305 days of milk yield in Murrah and indigenous breeds of the Terai region in Nepal[30]. Interestingly, the first parity had the lowest 305-day milk yield 1810.88±25.19 kg and highest 305-day milk yield of 2156.88±30.88 kg on fourth parity significantly, which contrasts with our current findings[31].

Effect on Daily and peak milk yield

In their study, researcher observed that Murrah buffaloes revealed mean daily milk yield of 8.842 ± 0.089 for the highest daily milk yield in the 2nd parity and 7.413 ± 0.253 in the seventh parity[32]. The results of our present study align with findings from other researcher who study different parities of Murrah buffaloes (Table 2). Additionally, average milk production of Murrah buffalo is recorded to be 9 litters[33].

Our study also found that the overall least squares mean (LSM) for peak milk yield (PMY) (Table 2) was consistent with previous research, which reported LSM values for PMY in Murrah buffaloes ranging from 7.92 ± 0.016 kg to 10.55 ± 0.07 kg[34] as well.

Milk yield in dairy animals refers to the average daily or total milk yield during a specified period, such as standard lactation or completed lactation. Peak yield, the maximum daily yield at any point, shapes the lactation curve and varies between species and breeds within species. The variability ($p > 0.001$) in milk yield is significant and varies depending on factors such as the type of buffalo, including the year, calving season, buffalo interaction during gestation, lactation length, and lactating age at maturity. The variation observed in management practices, such as the availability of feeds and fodders, may account for variations in peak yield.

The maximum milk yield of Murrah buffaloes varied between 7.92 ± 0.016 kg and 10.55 ± 0.07 kilograms[35] as reported by researcher. Researcher highlighted the influence of the season of calving, location, and parity on peak yield [36].

In Nepal, a study found that non-descript types of buffaloes were transformed into crossbreed Murrah buffaloes through natural/artificial selection and adaptation under socio-agroecological conditions.

Approximately 35 percent of crossbred/Murrah buffaloes were found in Nepal, with the remaining 85 percent being non-descript buffalo. This aligns with researcher observed that Graded Murrah produced the highest peak yield, while non-descript buffaloes followed suit[37].

V. Conclusion

Buffaloes in Nepal exhibit varying reproductive and productive traits due to geographical location and seasonal changes. Terai and Hill buffaloes necessitate distinct management strategies, while crossbred Murrah buffaloes require customized approaches due to seasonal effects. Future research should prioritize identifying and considering environmental factors to facilitate the development of appropriate management strategies.

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