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Natural increase, net replacement rate, output and population dynamic of Aceh cattle in Livestock Breeding and Forage Center of Indrapuri

R. Widyaningrum[1,3], I. G. S. Budisatria[2] and D. Maharani[1,*]

[1]*Department of Animal Breeding and Reproduction, Faculty of Animal Science, Universitas Gadjah Mada, Jl. Fauna No. 3, Bulaksumur, Yogyakarta 55281 - Indonesia*

[2]*Department of Animal Production, Faculty of Animal Science, Universitas Gadjah Mada, Jl. Fauna No. 3, Bulaksumur, Yogyakarta 55281 - Indonesia*

[3]*Permanent Address: Livestock Breeding and Forage Center, Indrapuri, Jl. Banda Aceh Medan Km 25, Reukih Dayah, Indrapuri, Aceh - Indonesia.*

**Corresponding E-mail : d.maharani@ugm.ac.id.*

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ABSTRAK

Penelitian ini bertujuan untuk mengestimasi *natural increase* (NI), *net replacement rate* (NRR), *output* dan dinamika populasi sapi Aceh di Balai Pembibitan Ternak Unggul dan Hijauan Pakan Ternak (BPTU-HPT) Indrapuri, Provinsi Aceh. Data *recording* ternak meliputi struktur populasi awal dan akhir tahun, data kematian, data kelahiran, data pengeluaran ternak, dan data pemasukan ternak tahun 2019 untuk menentukan NI dan NRR yang selanjutnya digunakan untuk estimasi *output*, sedangkan materi estimasi dinamika populasi adalah struktur populasi ternak selama lima tahun (2015-2019). Hasil penelitian menunjukkan nilai NI dalam kategori sedang yaitu 19,08%. Ketersediaan *replacement stock* jantan dan betina melebihi kebutuhan masing-masing 140,08% dan 73,33%, dengan nilai NRR jantan dan betina masing-masing 240,08% dan 173,33%. *Output* untuk sapi afkir jantan adalah 3,92%, sapi afkir betina 5,58%, sisa *replacement stock* jantan 5,49%, dan sisa *replacement stock* betina 4,09% dari total populasi. Dinamika populasi sapi Aceh tahun 2020 sampai 2024 diperkirakan akan naik rata-rata sebanyak 65 ekor atau 6,02%. Kesimpulannya, bahwa BPTU-HPT Indrapuri dapat dikategorikan sebagai wilayah sumber bibit, namun masih perlu upaya untuk meningkatkan *natural increase* yaitu dengan meningkatkan kelahiran minimal 32,77% dan menurunkan angka kematian maksimal 3,0% melalui manajemen yang lebih baik.

Keywords: dinamika populasi, natural increase, net replacement rate, output, sapi Aceh

ABSTRACT

This study aimed to estimate natural increase (NI), net replacement rate (NRR), output, and population dynamics of Aceh cattle at Livestock Breeding and Forage Center in Indrapuri, Aceh province. Data of population structure, mortality, birth rate, the number of animals entering the herd, and the number of animals released from the herd during 2019 were used for determining NI and NRR, and it is used for estimation of output. Population structure data (2015-2019) were used to estimate the population dynamics. The results showed that NI was 19.08% (medium category). The availability of replacement stock exceeded the need for replacement (140.08% for male and 73.33% for female); the NRR was 240.08% (male) and 173.33% (female). The output of Aceh cattle was 3.92% (culled male),

5.58% (culled female); the remaining replacement stocks were 5.49% (male) and 4.09% (female) of the total population. The population of Aceh cattle from 2020 to 2024 was expected to increase by 6.02% (65 heads) on average. In conclusion, that BPTU-HPT Indrapuri can be categorized as a beef cattle producing region, but still need efforts to increase natural increase by increasing birth rate minimum 32.77% and reducing mortality maximum 3.0%, in combination with better management systems.

Keywords: population dynamic, natural increase, net replacement rate, output, Aceh cattle

INTRODUCTION

Aceh cattle is a small-type cattle breed found exclusively in the Aceh province, Indonesia (Abdullah *et al*., 2008). It is classified as one of Indonesian local cattle breeds based on the Decree of the Minister of Agriculture Number 2907/Kpts/OT.140/6/2011. The breed is claimed to exhibit the following characteristics: resistance to parasites, thermotolerance, water scarcity, as well as ability to use high roughage diets, which are important characteristics in tropical production systems (Abdullah *et al.,* 2007). In Aceh Province, the total cattle population has reached 627,698 (2017), 354,741 (2018), 365,383 (2019) (Statistic Indonesia, 2019). The number of Aceh cattle is expected to decrease, so various studies are needed to increase the population and productivity of this Indonesian local cattle breed (Sofyan *et al*., 2020). As one of the technical implementation unit under the Ministry of Agriculture, the Livestock Breeding and Forage Center, Indrapuri (BPTU-HPT Indrapuri) has responsibilities to provide breeding stock and forage. All Aceh cattle in this station are selected especially for producing breeding stock and feeder stock. However, evaluation on the development of Aceh cattle population over the study area has never been carried out. Previews research performed by Kebede and Fetene (2012) in arid and semi-arid Ethiopia showed that there was a change in the population of cattle, sheep and camel as an impact of climate change and pastoralist need. Researchers were suggested in applying an appropriate technique in-stock replacement, implement conservation strategies as well as good pastoral management to create access to on-farm and off-farm to maintain sustainable breeds and diversify pastoral household income. Additionally, they underlined the importance of analyzing conservation status in various pastoral areas.

Moreover, assessing multi-temporal data of pastoral areas from 1980 to 1997 in Southern Ethiopia, Desta and Coppock (2002) mentioned the importance of awareness in livestock population dynamics to forecast the future of livestock production systems. Besides, they suggested including human population dynamics around the pastoral system that might interfere with the changes in livestock. In-line with this research, a recent study from Mutenje *et al.* (2020) stated that proper breeding strategies to improve food management over the study areas in Zimbabwe were having a significant impact to reduce livestock mortality. In Indonesia, a study shows that good management is required to increase livestock population, particularly in controlling livestock output by paying attention to natural increase, mortality, replacement stock, culled cattle, cattle income, and potential breeding stock supply capabilities (Budiarto *et al.,* 2013). A study performed by Talib *et al*. (2003) to assess population dynamics of Bali cattle suggested that declining population can be overcome by performing appropriate breeding strategies to reduce calf mortality, retain the prosperous bulls in the herds as well as to avoid slaughtering over productive cows.

A study on population dynamics was performed by Rohyan *et al*. (2016), Kusuma *et al.* (2017) and Ibrahim *et al.* (2016) to assess the capability of a specific region to be a source of breeding cattle by analyzing its natural increase, reproduction efficiency and the amount of replacement rate. As a livestock breeding and forage center, the researcher thought it is necessary to analyze the capability of BPTU Indrapuri to produce livestock in the future as well as assessing its breeding management based on an estimation of natural increase, net replacement rate, output, and population dynamics.

The output is the sum of animals that can be released per year and the remaining replacement stock (Sumadi *et al*., 2007). Where the remaining replacement stock is calculated based on the difference between the natural increase and the need for replacement livestock in a year (Ibrahim *et al*., 2016). Susanti *et al.* (2015) stated that output estimation is needed to be performed to avoid a sharp decline in the cattle population.

To predict the number of population over the year, it is also important to calculate the dynamic population estimation. Population dynamics can be estimated based on cattle population data over the last few years, while output can be estimated based on reproductive performance data in the last year (Kusuma *et al.,* 2017). Therefore, the purpose of this study was to estimation of natural increase, net replacement rate, output and population dynamics as a determination of beef cattle producing region.

MATERIALS AND METHODS

This study was conducted at the Livestock Breeding and Forage Center, Indrapuri, Aceh (BPTU-HPT Indrapuri). Recording data including population structure (at the beginning and the end of the year), mortality, birth rate, number of animals entering the herd and number of animals released from the herd during 2019 were used for determining of natural increase (NI) and net replacement rate (NRR), and it is used for estimation of output, while population structure data (2015 to 2019) were used for estimation of population dynamics: 687 (2015), 787 (2016), 834 (2017), 890 (2018), and 959 (2019) heads.

The variables observed included population composition and structure, mutation, deaths, births, natural increase, net replacement rate, output, and population dynamics. The NI and the need of replacement stock were used for estimation of output, while population structure (2015-2019) was used for estimation of population dynamics.

Data Analysis.

Average population, NI, NRR, output, and population dynamics were calculated using the following equation.

An average number of cattle a year according to (Sumadi, 2001):

$$Pt = (Paw + Pak) / 2$$

where Pt is the average number of cattle a year (head), Paw is the number of cattle in the first year of observation (head) and Pak is the number of cattle in the last year of observation (head).

The NI was estimated as the difference between the number of births and the number of deaths over a period (Sumadi, 2001). The following equation was applied for the estimation NI according to Kusuma *et al.* (2017):

Percentage of birth = [(Number of birth each year) / (Average population a year)] x 100%

Percentage of death = [(Number of death a year)/(Average population a year)] x 100%

Natural Increase (%) = (Percentage of birth – Percentage of death)

The NRR was obtained by calculating the number of young cattle that will be used as replacement stock divided by the need of replacement stock per year multiplied by 100% (Sumadi, 2001). The following equation was applied for the estimation NRR according to (Sumadi, 2001):

The length of time to use the elders (year) = maximum of old to breeding (year) – first mating old (year).

Replacement stock needs (%) = [(Number of adult/population) / (The length of time to use the elders (year))] x 100%

NRR = [(Natural Increase) / (Replacement stock needs)] x 100%

The output was estimated based on the number of culled cattle per year and the number of remaining replacement stock.

Remaining replacement stock of male cattle (%) = male NI (%) – need of replacement stock of male cattle (%)

Remaining replacement stock of female cattle (%) = female NI (%) – need of replacement stock of female cattle (%)

Culled male cattle (%) = need of replacement stock of male cattle (%)

Culled female cattle (%) = need of replacement stock of female cattle (%)

Total output = the number of remaining replacement stock of male cattle (%) + the number of remaining replacement stock of female cattle (%) + culled male cattle (%) + culled female cattle (%) (Sumadi *et al*., 2004).

Population dynamics was estimated based on time series data using the least squares method, which is a statistical procedure to find the best fit

for a set of data points by minimizing the sum of the offsets or residuals of points from the plotted curve (Supranto, 1993). The following equation was applied for the estimation of population dynamics:

$$Y = aX + b$$

where Y is the time series data, X is the difference between the current year and the reference year, a is the intercept and b is the regression coefficient.

RESULTS AND DISCUSSION

Population Structure

As shown in Table 1, the population of Aceh cattle at BPTU-HPT Indrapuri in 2019 was 959 heads. Of those, 19.60% were adult male cattle and 44.63% were adult female cattle. The higher number of female adult cattle than male adult cattle was due to rearing purposes. Aceh cattle were mostly raised for breeding purposes. However, in the young cattle group, a higher number of male cattle than female cattle was observed. Young male cattle can be used as both a bull candidate and a feeder stock candidate. In the population, BPTU-HPT Indrapuri still kept 58 heads of 11-18-year-old female cattle (6.05%) and 52 heads of 9-16-year-old male cattle (5.42%). To optimize the production and reproduction system, the old cattle should be culled. This is supported by Zainudin *et al.* (2014) which state that the reproductive ability of the brood over 10 years of age decline due to decreased physiological and hormonal status.

Mutation

Cattle mutation or movement in a region can be used to determine the ability of a breeding region to produce cattle (Ibrahim *et al*., 2016). As shown in Table 2, the number of cattle released from BPTU-HPT Indrapuri was 151 heads. In terms of population mutation, a total of 24 breeding stock (15.89%), 111 feeder stock (73.51%) and 16 culled cattle (10.60%) were observed. Up till now, the replacement stock of Aceh cattle at BPTU-HPT Indrapuri was only obtained from its own breeding center and thus, the number of cattle entering the herd was higher than the number of cattle released from the herd. In this regard, the availability of cattle in the breeding center exceeds the need for replacement stock (Kusuma *et al*., 2017).

Natural increase

Natural increase is a statistic that can be used to estimate output (the number of cattle which can be out from the farm). Output can be estimated based on the number of culled cattle per year and the number of remaining replacement stock. The remaining replacement stock is the difference between natural increase and the number of replacement stock needs. Meanwhile, the natural increase can be defined as the difference between the number of births and the number of deaths occurring a year (Sumadi, 2017). Kgosikoma and Batisani (2014) added that the birth rate and death rate can be used as an indicator of livestock production performance.

Table 1. Population Structure of Aceh Cattle at BPTU-HPT Indrapuri in 2019

Item	At the Beginning of the Year	At the End of the Year	Average	Average Percentage (%)
Adult male	185	191	188	19.60
Adult female	385	471	428	44.63
Young male	78	105	92	9.54
Young female	65	96	81	8.39
Male calf	119	55	87	9.07
Female calf	111	57	84	8.76
Total male	382	351	367	38.22
Total female	561	624	593	61.78
Total population	943	975	959	100.00

Adult cattle: >24 months of age, young cattle: 11-24 months of age, calf: 0-10 months of age (Alfian, 2012)

Table 2. Total Population, Components and Natural Increase of Aceh Cattle at BPTU-HPT Indrapuri in 2019

Item	Number (Head)	% of the Average Population	% of the Average Population of Cows as Breeding Stock	Birth Ratio (%)
Population at the beginning of the year	943			
Population at the end of the year	975			
Average population	959			
Average population of cows as breeding stock	428	44.63		
Mutation	151	15.75		
Birth	223	23.25	52.10	
Male	110	11.47	25.70	49.33
Female	113	11.78	26.40	50.67
Death	40	4.17		
Adult	10	1.04		
Young	7	0.73		
Calf	23	2.40		
Natural increase (NI)	183	19.08		
Male natural increase	90	9.41		
Female natural increase	93	9.67		

Birth Rate

The birth rate is the number of births per female per unit of time (Krebs, 2009). The number of births of Aceh cattle in 2019 was 223 heads (52.10% of the total cows and 23.25% of the total population) (Table 2). Female cattle gained the higher birth rate than male cattle (50.67% vs 49.33%). This is a good composition for replacement stock as supported by Putra *et al.* (2015) which states that the percentage of births relatively high number of females compared to the number of the birth of a male is a good composition for replacement stock. The birth rate observed in this study was higher than 30.89% in beef cattle population in Poso regency, Indonesia (Tanari *et al*., 2011), but lower than 53.98% (Ibrahim *et al*., 2016), 51.66% (Kutsiyah, 2017), 75.48% (Kusuma *et al*., 2017), 58.20% (Susanti *et al*., 2015), 57.93% (Putra *et al*., 2015) and 72.27% (Samberi *et al*., 2010).

The total birth rate observed in this study was quite low. Hafez (1993) defined that birth rate (>90%) and weaning rate (>85%) are the key determinants of high reproductive efficiency. The lower birth rate in this study might be due to the presence of 58 old cows (6.05%). Productive and reproductive performances of old cattle usually decline due to decreased physiological and hormonal status and interfere with the reproduction of livestock during ovulation, estrus, fertility, and pregnancy (Zainudin *et al*., 2014).

Death rate

The death rate is the ratio of the total number of deaths over total number of animals during the survey year (Kgosikoma and Batisani, 2014). The total death rate of Aceh cattle in 2019 was 4.17% (2.40% for calves, 0.73% for young cattle, and 1.04% for adult cattle). In some previous studies, lower death rates were observed: ≤3.0% (Sugiono, 2019), 0.72% (Ibrahim *et al*., 2016), 0.12% (Kusuma *et al*., 2017), 2.23% (Kutsiyah, 2017),

0.82% (Rohyan *et al*., 2016), 0.68% (Putra *et al*., 2015), 2.7% (Tanari *et al*., 2011) and 1.33% (Samberi *et al*., 2010). Deaths lead to a net reduction in herd size (Desta and Coppock, 2002), so as to increase the population should be improved by applying strategies to reduce calf mortalities, decrease the slaughter of productive cows, and prepare and retain appropriate bulls in the herds (Talib *et al*., 2003).

The most common causes of death in Aceh cattle of BPTU-HPT Indrapuri are dietary deficiency (32.5%), tympani (22.5%), digestive tract obstruction by corpora aliena (17.5%), accident 15%, pneumonia 5%, diarrhea (2.5%), heat stress (2.5%) and complications (2.5%). This dietary deficiency was mainly due to the overcapacity of the cage which makes some cattle unable to compete for feed. Some efforts have been made by BPTU-HPT Indrapuri to reduce the risks of death by improving the quality and quantity of diets, as well as the maintenance systems. This effort in conjunction with the statement of Talib *et al.* (2001) indicated that under good nutrition and management calf mortalities can be reduced.

The NI can be categorized as low, medium and high. The assessment of NI groups is carried out by looking at the percentage of the adult female cattle in the population, then divided into three percentages for high, medium, and low categorization (Kusuma *et al*., 2017). Based on the average number of female adult cattle in Indrapuri (2019) was 44.63%. Thus, the NI values in this study were high (29.77% to 44.63%), medium (14.88% to 29.76%) and low (0 to 14.87%), but in general the NI of Aceh cattle was medium (19.08%) as shown in Table 2.

The NI observed in this study was higher than that reported in previous studies: 12.13% (Tanari *et al*., 2011) and 18.18% (Samberi *et al*., 2010), but lower than NI of 22.06% (Ibrahim *et al*., 2016), 27.96% (Kutsiyah, 2017), 40.78% (Kusuma *et al*., 2017), 44.68% (Rohyan *et al.,* 2016), 24.39% (Susanti *et al*., 2015), 29.46% (Putra *et al*., 2015), and 21.72% (Tonbesi, 2009). These differences indicate variation in natural increase among beef cattle populations in Indonesia. The NI value is influenced by the death rate. The highest natural increase is obtained if all the adult female cattle in the population give birth to all without dying (Susanti *et al.,* 2015). Furthermore, the NI determines the number of replacement stock needs and the number of culled cattle (Tanari *et al*., 2011). A higher NI indicates a higher number of productive adult female cattle, which is characterized by higher birth rate and lower death rate (Budiarto *et al*., 2013). The rearing management of Aceh cattle at BPTU-HPT Indrapuri therefore still needs improvement to increase the birth rate and to decrease the death rate. Based on the NI parameters in the study area and the maximum death rate max 3.0% by Sugiono (2019), the birth rate must be increased by a minimum of 32.77% of the population to achieve a high NI value.

Net Replacement Rate

Longevity, natural increase, and livestock population are important data that can be used to estimate the need for animal supply (Hardjosubroto, 1994). In a livestock breeding program, it is important to consider longevity as it determines productive and reproductive performances (Anggraini *et al*., 2016). The longevity of beef cattle is about 8 (male) and 10 (female) years, while the age at which the cattle can be first bred is at about 2-3 (male) and 1.5-2 (female) years (Vierman, 2018), so the length of time to use the elder is 5 years (male) and 8 years (female). To estimate the need for animal supply, NRR should be estimated.

Estimation of net replacement rate (NRR) aims to determine the ability of a breeding region to produce cattle or replacement stock over a period of time. The NRR of more than 100% indicates that a livestock breeding region is able to fulfill the need for replacement stock (Sumadi, 2001). Based on our observation, the replacement stock of Aceh cattle at BPTU-HPT Indrapuri was only obtained from its own breeding center.

The estimation of NRR indicated that BPTU-HPT Indrapuri has able to fulfill the need of replacement stock, exceeding the need of replacement stock (140.08% for male and 73.33% for female) as shown in Table 3. The NRR estimated in this study was higher than 96.18% (male) and 126.41% (female) in Madura cattle (Kutsiyah, 2017), 53.94% (male) and 123.99% (female) in PO cattle in the Kebumen regency (Kusuma *et al*., 2017), 87.68% (male) and 121.03% (female) in beef cattle population in Pesisir Selatan regency (Putra *et al*., 2015), but lower than 234.28% (male) and 189.59% (female) in Bali cattle in Yapen Islands (Samberi *et al*., 2010).

NRR values in the study area are highly likely due to the long use of males and females. Replacement stock needed is the percentage of an

adult in the population divided by the length of time to use the elder (Sumadi, 2001). According to Daly (1980), the length of use of males in breeding is two to three years. The overly long use of males can cause the genetic diversity of an inter-individual trait to be small so that selection on the nature of production becomes less effective (Daniel, 1980).

Output

The output is defined as the ability of a region to produce beef cattle, or in other words, the number of cattle in a breeding region that can be released from the herd without threatening the cattle population (Sumadi *et al*. 2004). Output can be estimated based on the number of animals that can be released per year and the number of remaining replacement stock (Sumadi *et al*., 2007). Output is affected by natural increase, the greater natural increase value, the higher the output value (Sumadi, 2017).

The output value of Aceh cattle was 19.08% (Table 4), which was equal to the NI value, indicating an equilibrium in the observed population (Kusuma *et al*. (2017). If the output value is lower than the NI value, there will be an increase in population size, and vice versa.

Population Dynamics

The population dynamics of Aceh cattle was estimated using time series analysis. The population of Aceh cattle from 2015 to 2019 increased by 8.77% (68 heads) on average (Table 5). The increase in population size can be determined by estimation of net increase based on the data collected over the last five years (Sumadi, 2001).

The population dynamics of Aceh cattle from

Table 3. Net Replacement Rate of Aceh Cattle at BPTU-HPT Indrapuri in 2019

Item	Number (head)	Percentage (%)
Male		
Need of male replacement stock	38	3.92
Availability of male replacement stock = NI	90	9.41
Male NRR		240.08
Female		
Need of female replacement stock	54	5.58
Availability of female replacement stock = NI	93	9.67
Female NRR		173.33

NRR : Net Replacement Rate

Table 4. Output Analysis of Aceh Cattle at BPTU-HPT Indrapuri in 2019

Item	Number (head)	Percentage (%)
Culled cattle		
Male	38	3.92
Female	54	5.58
Remaining cattle as replacement		
Male	52	5.49
Female	39	4.09
Total Output	183	19.08

Table 5. Population Dynamics of Aceh Cattle at BPTU-HPT Indrapuri from 2015 to 2019

Year	Population	Growth	
		Number (head)	Percentage (%)
2015	687	-	-
2016	787	101	14.64
2017	834	47	5.91
2018	890	56	6.72
2019	959	70	7.81
Average	831	68	8.77

Table 6. Estimation of Population Dynamics of Aceh Cattle from 2020 to 2024 Based on Time Series Analysis

Year	Population	Growth	
		Number (head)	Percentage (%)
2020	1,025	66	6.92
2021	1,090	65	6.31
2022	1,155	65	5.94
2023	1,220	65	5.61
2024	1,284	65	5.31
Average	1,155	65	6.02

2015 to 2019 increased, though there is a mutation (60 heads or 6.26%) and mortality (60 heads or 6.26%). This increase might be due to a higher birth rate (205 heads or 24.85% during the last five years) than mutation rate and death rate. Population dynamics increases in line with the increased NI. The high NI can be achieved by keeping productive cows and culling or removing unproductive cows from the herd (Sumadi, 2001).

The population dynamics was estimated by analysis of time series with equation Y= 64.75X + 831.1. Based on this equation, the population of Aceh cattle from 2020 to 2024 was predicted to increase by 6.02% (65 heads) on average (Table 6). This increase was predicted with fixed technical coefficients, including natural increase, the percentage of adult cattle, age at first mating, longevity, birth rate, death rate and migration (Tonbesi, 2009; Budisatria *et al*., 2016).

The output of Aceh cattle from 2020 to 2024 was estimated based on the population dynamics (2020–2024) and output values in 2019. As shown in Table 7, the output values showed a trend of increasing year by year due to increased population size, and the availability of cattle exceeded the need for replacement stock. Therefore, BPTU-HPT Indrapuri can be categorized as a beef cattle producing region.

CONCLUSION

Natural increase of Aceh cattle was 19.08% (medium category). The net replacement rates were 240.08% (male) and 173.33% (female), so the availability of replacement stock exceeded the need for replacement (140.08% for male and 73.33% for female). The output of Aceh cattle was 3.92% (culled male) and 5.58% (culled

Table 7. Estimation of Output in Aceh Cattle Population from 2020 to 2024

Year	Population	Output				Number (head)	Percentage (%)
		Young		Culled			
		Male	Female	Male	Female		
2020	1,025	56	42	40	57	196	19.08
2021	1,090	60	45	43	61	208	19.08
2022	1,155	63	47	45	64	220	19.08
2023	1,220	67	50	48	68	233	19.08
2024	1,284	71	53	50	72	245	19.08
Average	1,155	63	47	45	64	220	19.08

female), and the remaining replacement stocks were 5.49% (male) and 4.09% (female). There was a trend of increase in population dynamics from 2020 to 2024 (6.02% or 65 heads per year). This study suggests that BPTU-HPT Indrapuri can be categorized as a beef cattle producing region, but still need efforts to increase natural increase by increasing birth rate minimum 32.77% and reducing death rate maximum 3.0%.

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