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

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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), 5.49% (sisa replacement stock jantan), and 4.09% (sisa replacement stock betina) from total population. 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
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, high tolerance, 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 on population dynamics was 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.

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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):

\[ Pt = \frac{(Paw + Pak)}{2} \]

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):  

\[ Pt = (Paw + Pak) / 2 \]

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

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

\[ Natural\ Increase\ (%) = (Percentage\ of\ birth – Percentage\ of\ death) \]

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):

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

\[ Replacement\ stock\ needs\ (%) = \frac{(Number\ of\ adult/population)}{(The\ length\ of\ time\ to\ use\ the\ elders\ (year))} \times 100\% \]

\[ NRR = \frac{[(Natural\ Increase)\ /\ (Replacement\ stock\ needs)]}{100\%} \]

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

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

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

\[ Culled\ male\ cattle\ (%) = need\ of\ replacement\ stock\ of\ male\ cattle\ (%) \]

\[ Culled\ female\ cattle\ (%) = need\ of\ replacement\ stock\ of\ female\ cattle\ (%) \]

\[ Total\ output = \text{the number of remaining replacement stock of male cattle} + \text{the number of remaining replacement stock of female cattle} + \text{culled male cattle} + \text{culled female cattle} \ (Sumadi\ et\ al.,\ 2004). \]

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)
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 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).

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                         |                                                       |                 |
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 our observation, 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 Pesiris 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

| Item                                | Number (head) | Percentage (%) |
|-------------------------------------|---------------|----------------|
| Culled cattle                       |               |                |
| Male                                |               |                |
| 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 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          |
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 female)
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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Table 7. Estimation of Output in Aceh Cattle Population from 2020 to 2024

| Year | Population | Output Number (head) | Percentage (%) |
|------|------------|----------------------|----------------|
|      |            | Young Male | Female | Culled 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          |
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