Optimum sustainable population estimation of *Rusa timorensis* in Pananjung Pangandaran nature reserve and natural park

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Abstract. Three main objectives of conservation are protection, preservation and sustainable utilization. Timor deer is one of Indonesian wild animal that has many benefits and high economic value. But the current Timor deer population continues to decrease with population decline rate of 10% in each generation. It caused by harvesting without considering sustainability. Therefore it is necessary to manage the population for Timor deer, so it can be available for sustainable use. Optimum sustainable population is a threshold population size for sustainable harvesting. The purpose of this study is to estimate the optimum sustainable population size so Timor deer can be utilized sustainably in the future. The method used was projecting the actual population by using Leslie matrix (Density Dependence) so that population growth can be seen. The optimum sustainable population is the size of the population with the highest growth rate. The time used for this population projection is 100 years. Based on the results of this research, the optimum sustainable population size for Timor deer in the Pananjung Pangandaran nature reserve and Natural Park is 751 individuals and the optimum sustainable population size will be achieved in 2047.

1. Introduction

Harvesting of wildlife to meet human needs can decline the population and lead to extinction. On the other hand human needs that continue to grow due to increasing human population cannot be avoided. Utilization of biological natural resources in Indonesia has been regulated in Law (Undang-Undang) No. 5 of 1990 which states that "Indonesia's living natural resources and ecosystems that have an important role in life are gifts of God Almighty, therefore they need to be managed and utilized sustainably, harmonious and balanced for the welfare of the Indonesian people in particular and humanity in general, both present and future " This is in accordance with the three principles of conservation, namely preservation, protection and sustainable use. But in reality the harvesting of wild animals in nature is carried out not based on scientific calculations and does not considering for its sustainability in the future.

One of the wildlife that has the potential to be used is Timor deer [1]. The Timor deer which has a scientific name (*Rusa timorensis* Blainville 1822) is one of Indonesia's wild animals that has many benefits and high economic value. Deer can be used as a producer of meat, skin, and antler. Almost all
parts of the deer’s body can be utilized, besides meat, skin and antler, testicles, innards and velvet can also be used [2]. The young antlers (velvet) are believed could be increase the body metabolism so that it is widely used as an impotence medicine [2]. Velvet prices that has been dried can cost US $ 120 per kg [3]. Since the Dutch colonial period the Timor deer was protected by ordinance and Wildlife Protection Act No. 134 and 266 in 1931 [4]. This law is a government protection effort to prevent the extinction of deer species in Indonesia. The existence of a law protecting for Timor deer does not necessarily guarantee preserve Timor deer populations in Indonesia. The Timor deer population continues to decline in each generation [5]. Therefore it is necessary to manage the population for Timor deer, so that Timor deer can be used sustainably.

Sustainable optimum population is a condition where the population growth rate will be maximal. With the maximum growth rate, the population will increase rapidly, so harvesting can be done without disturbing the balance of the population [6]. The optimum population size is among the minimum sustainable population size with the existing carrying capacity [7]. Information about the size of the optimum sustainable population is highly needed in the management of the exploited wildlife. One way that most often used to determine sustainability harvest number of wildlife populations is the maximum sustainable yield (MSY) [8]. MSY has a disadvantages the number of harvesting individuals is general, we do not know which individuals that allow to be harvested. According to Santosa, harvesting must be specific to certain sexes and age classes, so it is not disturb population stability [9]. Maximum sustainable yield number also can be overexploitation for small population or exploited population [8]. This study aim is to determine the optimum sustainable population size of Timor deer in every age classes, as a target for Timor deer to be used sustainably in the future.

2. Material and method
To determining the Optimum sustainable population we need the actual population size of Timor Deer in Pananjung Pangandaran Nature Reserve and Natural Park. The actual population size was obtained from direct census, we used concentration count census technique to count the Timor deer population. The actual population size was projected by using Leslie matrix combine with Density Dependence model so that population growth can be seen in every age class. The optimum sustainable population is the size of the population with the highest growth rate. The time used for this population projection is 100 years.

The population used as the initial population in the Leslie matrix projection is only the female population. Population size in males will be obtained from a comparison of sex ratios. The Leslie matrix equation that is closely related to the density used is as follows:

\[
M \times Q_t^{-1} \times N_t = N_{t+1}
\]

\[
M = \begin{bmatrix}
F_{tt} & F_{tt} & F_{dt} \\
F_{tt} & 0 & 0 \\
0 & F_{tt} & 0
\end{bmatrix},
N_t = \begin{bmatrix}
N_{tt} \\
N_{tt} \\
N_{tt}
\end{bmatrix},
Q_t^{-1} = \begin{bmatrix}
1/q_{tt} & 0 & 0 \\
0 & 1/q_{tt} & 0 \\
0 & 0 & 1/q_{tt}
\end{bmatrix}
\]

Fx = fecundity in every age class
Px = the proportion of individuals surviving in every age interval
Nt = population size in year t
Q = growth limiting factor

\[
q_t = 1 + \alpha, N_t
\]
\[
\alpha = (\lambda - 1)/K
\]

\[
\lambda = e^r \text{ (finite growth rate)} \ [10]
\]
\[
r = \text{growth rate}
\]
K = carrying capacity
In compiling the Leslie matrix, the time interval between age classes must be the same. The age determination of Timor deer in field only based on its morphology then categorized into four age classes i.e. Infant, juvenile, sub adult and adult [11]. Because of the difficulty in determining the age of in the field, in this study the initial population for each age class will be divided by the time interval for each age class. So that we get a same time interval of 1 year. Matrix multiplication is aided by Microsoft Excel 2007.

3. Result and discussion

Based on the results of the census with the concentration count method, the actual population of Timor deer in Pananjung Pangandaran Nature Reserve and Natural Park is 68 individuals in detail as in the following table:

| Age Classes | Population (Individual) |
|-------------|-------------------------|
|             | Male | Female | Total |
| Juvenile    | 5    | 11     | 16    |
| Sub- adult  | 7    | 14     | 21    |
| Adult       | 14   | 17     | 31    |
| Total       | 26   | 42     | 68    |

In the age structure that composes the population of Timor deer in TWA and CA Pananjung Pangandaran the highest number of individuals is in the adult age class, then the age class of sub adult and the least is in the age class of juvenile. This condition will form an inverted pyramid where the population will experience a setback. But because each age class has a different age interval, the actual age structure is the number of individuals in that age class divided by the age interval. After divided by the age interval, the age structure shows the condition of developing population. Where the number of juvenile more than the number of individuals in the age class above.

The female actual population was projected by Leslie matrix that combine with density dependent [12]. As a result from the projection, we get the coming years population based on the age class. The population projected in this study was 110 years. The difference in population size each year is presented in the following graph.

![Population Size Differences](image_url)

**Figure 1.** Timor deer population differences each year.
Figure 1 shows the highest differences on population size will be obtained in 2047. The highest population differences means the largest number of production on that year. We can conclude that the population condition and composition on that year is the optimum size. In 2047 the size of the deer population in TWA and CA Pananjung Pangandaran reached 751 with 153 females, 77 males, 186 females, 93 males, 132 females and 110 males. While the optimum sustainable population size in Alas Purwo National Park is 21,682 tails with 6,386 individual females, 1,597 male females 5,277 adolescent females, 1,319 adolescent males, 4,735 adult females, and 2,367 adult males.

4. Conclusion
The optimum sustainable population size for Timor deer in the Pananjung Pangandaran nature reserve and natural park is 751 individuals with details 153 juvenile females, 77 juvenile males, 186 sub-adult females, 93 sub-adult males, 132 adult females and 110 adult males. The optimum sustainable population size will be achieved in 2047.

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