Aspects of population ecology of the leopard (Panthera pardus) in Ruhuna National Park, Sri Lanka

Mangala de Silva* and B.V.R. Jayaratne**

Abstract
A population of leopards was studied using daily observations (from 0600 to 1800 hrs) of the Park officials for two years in an area of 140 km² in Ruhuna National Park (RNP). The study area included a coastal region, which consists mainly of grassland interspersed with patches of scrub, and an inner region in which the dominant vegetation is scrub. There appear to be 16 adult leopards in the study area (average density 0.1 km⁻²), but the density was higher in the coastal region (0.3 km⁻²) than in the inner region (0.07 km⁻²). This is probably due to the higher density of prey species in the coastal area and the relative ease with which the prey can be captured in the scrub-grassland interphase.

Unlike male leopards, females appear to have overlapping ranges. The range of a female appears to overlap with those of several males and vice versa. During daylight hours the leopard is most active from 0700-0900 hrs and after 1600 hrs.

The population has a sex ratio of 1:1.3 favouring females. Breeding occurs throughout the year but two peaks were seen during the periods March to May and October to November. Cubs were seen during the periods of March to May and September to October. Adult females were observed with one to three cubs, but females with two cubs were the most common.

The only other carnivore that may offer some competition to the leopard in RNP is the crocodile. There appear to be over 300 crocodiles of the species Crocodylus palustris and C. porosus, of which the former is more common, in the numerous waterholes of the park.

Keywords: leopard, Panthera, Carnivora, population ecology, reproduction, Sri Lanka, tropical.

Introduction
The leopard, Panthera pardus has several subspecies and a wide distribution in Africa, the Middle East and Asia. The subspecies P. p. fusca Meyer is confined to India, Burma and Sri Lanka (Phillips, 1984). Panthera pardus, the largest terrestrial carnivore in Sri Lanka, was common in most large forests a few decades ago. Because of poaching and habitat degradation it is now almost entirely confined to protected areas. The reduction of forest cover could reduce the leopard habitat directly as well as indirectly by reducing some forest areas to isolated small patches that cannot sustain a population. Its habitats in the island range from lowlands up to the highest mountains. Ruhuna National Park (RNP) is one of the few areas in which the leopard is still common.

* Department of Zoology, University of Peradeniya, Peradeniya, Sri Lanka.
** Department of Wildlife Conservation, Ruhuna National Park, Palatupana, Tissamaharama, Sri Lanka.
Being a very elusive animal which is mostly active at night, the leopard is difficult to study in the wild except by indirect means. Also its color pattern blends well with the background scrub forest making it difficult to observe during daytime. Previous population studies on the Sri Lankan leopard include Eisenberg & Lockhart (1972), who studied the leopard population of the Wilpattu National Park in their Large Mammal Survey during the period of July 1968 to October 1969, and Santiapillai et al. (1982), who studied the population in RNP-Block I by seasonal surveys during the period of May 1978 to May 1980.

The present study in RNP-Block I differs from the previous ones since it is mainly based on daily observations of several people for a greater length of time.

Materials and methods

Study area. Ruhuna National Park (RNP), which is situated in the south-eastern part of Sri Lanka, has a semi-arid climate because of the very seasonal and limited amount of rain it receives (750-1000 mm yr⁻¹, Somasekaram, 1988). Together with the other reserves contiguous with it, RNP covers an area of about 1500 km² and is divided into several blocks for administrative reasons (but not on ecological criteria). Of these, Block I occupies an area of only 140 km². However, the wildlife of Block I, in comparison to that of other blocks, can easily be studied in a variety of habitats because of the good network of roads traversing the area (Fig. 1). Its vegetation consists mainly of scrub forest and grasslands. The coastal region (Fig. 1) consists of grasslands interspersed with scrub forest. The inner region consists mainly of scrub although a narrow belt of high forest characterized by Terminalia arjuna is present along the Menik River. The limited tract of high forest along the banks of the Menik River and the saline flats and sand dunes along the sea coast are the other major habitats. Because of its wide stretches of grasslands and numerous waterholes, Block I also contains a high population of herbivores: elephant (Elephas maximus), buffalo (Bubalus bubalis), sambar (Cervus unicolor), spotted deer (Axis axis) and small herbivores. Details of the physiognomy, climate and vegetation of Block I can be found in Müller-Dombois (1968), Balasubramaniam et al. (1980), Chambers et al. (1983) and de Silva et al (1993).

Methods. The present study is based on the sightings of leopards in the RNP-Block I by park staff and the personal observations of the present authors during the period March 1991 to March 1993.

Guides accompanying visitors (in vehicles) to the park, and other park officials were requested to keep a record of their sightings of leopards. The guides are able and experienced in spotting leopards in the scrub forest. Information on the time and place of sighting, number, sex, category (e.g. adult male, adult female, adult (when sex cannot be ascertained with certainty, which is often the case), subadult and cub), activity at the time of sighting (whether lying in wait, stalking prey, feeding on prey, etc.) were thus obtained. Guides were personally interviewed whenever clarification was required.

In estimating the number of sightings, repeat observations by different trackers at the same time and same place were eliminated, although the observations at the same place but at different times of the day are taken for estimating
frequency of leopards at different times. The park is open from 0600 to 1800 hrs to visitors and observations were made during this period. The park was closed to visitors during the period of 01 September to 15 October in both 1991 and 1992 and records for these periods are therefore not available.

Each guide takes visitors by vehicle, usually three to four times per day, to various areas of the park. The coastal area (Fig. 1) is more often covered than the inner region of the park since the wildlife is more abundant and more easily seen in the grasslands of the coastal area than in the scrub of the inner area (de Silva, 1992; de Silva et al., 1993; pers. obs.).

In order to assess the relative frequencies of the coverage of coastal and forest areas by visitors, the areas covered by different guides were noted for several days. It was found that the coastal area is covered about eight times more than the inner forest area and that the eastern part of the park is rarely visited except by those that stay in the two bungalows located in that part.

Results

The number of sightings are recorded in Fig. 2 at the approximate areas of the sightings. The highest number of males and females observed in any single sighting in each area is also indicated in Fig. 2. Since the leopard is a territorial animal moving from a central core area to the periphery of its home range (Eisenberg & Lockhart, 1972), it is assumed that the highest number of sightings within an area is indicative of the core area within a range. The probable ranges of males and females, estimated by distribution and frequency of observations, are also indicated in Fig. 2. It must be emphasized that the leopards were neither identified individually nor were their ranges identified by following their movements. Thus, the ranges estimated here are at best educated guesses that could be made under the circumstances and have to be treated only as working estimates. The low frequency of observations in the denser inner forest area, especially in the eastern region, makes it more difficult to estimate the ranges of leopards in these regions. From the analysis, it appears that there are about 9 adult leopards (4 males and 5 females) in the coastal area, which gives a density of about 0.3 individuals per km². There appear to be seven adult individuals (3 males and 4 females) in the inner scrub area, which gives a density of about 0.07 individuals per km² for the scrub area. Thus, the overall density and the sex ratio of leopards in Block I would be about 0.11 individuals per km² and 1:1.3 favouring females, respectively. This ratio differs from that of 1.2:1 favouring males estimated from the total number of observations during the study period. However, there are reasons not to rely on the latter estimate (see below).

The presence of two adult females with a single male, and on one occasion two adult females together indicate that females may have overlapping ranges. Two adult males were never encountered together, which indicates that the ranges of males do not overlap to any significant extent. The range of a female appears to overlap with those of several males and vice versa. The range of a male in the coastal area appears to be about 10 km² in extent whereas that of a female appears to be about 8 km². In the inner forest area the range of a male appears to be about 33 km² and that of a female appears to be about 25 km². Most of the observations were based on solitary sightings (Table 1). Male-female pairs as
**Figure 1.** Map of Ruhuna National Park - Block I showing waterholes (stippled), rocky outcrops (hatched) and roads.

**Figure 2.** Number of sightings and estimated ranges of male and female leopards in the study area. The numbers indicate the number of sightings at each area. The number preceding M, F and A indicate the number of males, females and unsexed adults that have been sighted simultaneously.
well as a single male accompanying two females were also observed, but the latter grouping was observed only on a few occasions (Table 1). Leopards were observed during all months. Although the park was closed to visitors during the month of September the park officials on patrol duty have observed leopards. However, these observations were not taken into consideration except for recording the presence of cubs. The frequency of sighting differed from month to month. More leopards were observed during the months of March, April, May, August, November and December (Fig. 3). Of these dates, except for August which was the peak drought period, other times were during the rainy months (Fig. 5). The frequency of leopard observations at different hours during the daytime is given in Fig. 4. It appears that during daylight hours leopards are most active between 0700 and 0900 hrs and after 1600 hrs. Observed pairing of males and females indicates that breeding occurs during most months, if not all (Fig. 5). However, two peaks of pair associations were observed during the intervals of March to May and October to December, which coincide with rainy seasons (Fig. 5). Cubs accompanying mothers were observed during the periods of March to May and September to October. The number of cubs accompanying the mothers varied from one (19%) to three (5%), the most frequent being two cubs (76%).

Discussion
The high density of the leopard population in the coastal area of RNP is very probably due to both a higher availability of prey and the effective hunting habitat provided by the abundant scrub-grassland interphase. The biomass of large herbivores is much higher in the coastal region than in the interior region (Table 2). Personal observations indicate that the same is true for other minor herbivores and small mammals, e.g. har: *Lepus nigricollis*, mongooses (*Herpestes spp.*), porcupine (*Hystrix indica*), etc. in the park except perhaps for the musiac (*Muntiacus muntjac*), mouse deer (*Tragulus meminna*), grey langur (*Semnopithecus priam*) and the toque monkey (*Macaca sinica*). The scrub within or at the edge of

<table>
<thead>
<tr>
<th>Grouping</th>
<th>Frequency</th>
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<tbody>
<tr>
<td>Solitary</td>
<td>0.749</td>
</tr>
<tr>
<td>(Adult male)</td>
<td>0.175</td>
</tr>
<tr>
<td>(Adult Female)</td>
<td>0.058</td>
</tr>
<tr>
<td>(Adult unsexed)</td>
<td>0.512</td>
</tr>
<tr>
<td>(Subadult)</td>
<td>0.004</td>
</tr>
<tr>
<td>Male+female pair</td>
<td>0.147</td>
</tr>
<tr>
<td>Male+2 females</td>
<td>0.019</td>
</tr>
<tr>
<td>Female+single cub</td>
<td>0.015</td>
</tr>
<tr>
<td>Female+2 cubs</td>
<td>0.062</td>
</tr>
<tr>
<td>Female+3 cubs</td>
<td>0.004</td>
</tr>
<tr>
<td>Female+3 subadults</td>
<td>0.004</td>
</tr>
</tbody>
</table>

Table 1. Frequency of observation of different groupings of leopards in Ruhuna National Park (n=259).
Figure 3. Frequency of sightings of leopards during different months.

Figure 4. Frequency of sightings of leopards during different hours of daytime.

Figure 5. Frequency of sightings of males and females together during different months. The months in which the cubs were sighted and the average monthly rainfall for the period 1972-1992 are also indicated.
grassland provides effective cover for the leopard to remain hidden and attack the prey as the latter emerges or go back to the forest from grasslands or waterholes. The grassland itself is not a good hunting habitat since the leopard has a low speed of pursuit and does not pursue the prey for a long distance. In Serengeti Park, of the terrestrial carnivores (lion (*Panthera leo*), cheetah (*Acinonyx jubatus*), leopard, spotted hyena (*Crocuta crocuta*) and hunting dog (*Lycaon pictus*)), the leopard has the lowest speed of pursuit (up to 60 km hr⁻¹) except for the lion, the lowest distance from prey when the chase starts (5-20 m), the lowest distance of pursuit (up to 50 m) and the lowest success rate (5%) (Bertram, 1979). Myers (1976) also points out that higher densities of leopards are likely in areas where the 'edge effect' is high. The scrub-grassland interphase is more extensive in the coastal region than in the inner part in RNP. Since the scrub contains mostly trees with a height of less than 5 m, it provides few strong perches suitable for the leopards to remain hidden in order to attack prey.

Santiapillai *et al.* (1982) estimated that there are 25 leopards in Block I of RNP (a density of 0.18 individuals per km²), but they did not record whether the densities were different between coastal and inner regions. The overall density estimated in the present study (0.11 individuals/km²) is lower than their estimate. Eisenberg & Lockhart (1972) estimated that there were 20 resident leopards in Wilpattu National Park (WNP), i.e. a crude density of about 0.03 individuals per km². They arrived at this figure by taking into account the extent of the park (about 580 km²) and the estimated individual home range of about 29 km². Since these authors also point out that a considerable overlap occurs between the male and female ranges, the actual density is probably higher. The higher density of leopards in the RNP-Block I may well be due to the higher density of herbivore prey species in comparison to that in the WNP (Table 3).

In estimating the density of leopards in WNP in relation to the herbivore biomass available, Eisenberg & Lockhart (1972) assumed that an adult leopard requires about 950 kg of food (flesh) per year and this amount could be supplied by the 13,600 kg of suitable herbivore standing crop taking into account a 10%

### Table 2. The estimated biomass (kg km⁻²) distribution of the major herbivores in coastal grassland and inner scrub areas of RNP (Block I) (data from de Silva, 1992).

<table>
<thead>
<tr>
<th></th>
<th>Coastal</th>
<th>Scrub</th>
<th>Ratio (coastal:scrub)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elephant</td>
<td>3341.5</td>
<td>111.1</td>
<td>30.1:1</td>
</tr>
<tr>
<td>Buffalo</td>
<td>3692.9</td>
<td>365.1</td>
<td>10.1:1</td>
</tr>
<tr>
<td>Spotted deer</td>
<td>1536.7</td>
<td>364.8</td>
<td>4.2:1</td>
</tr>
<tr>
<td>Sambar</td>
<td>1625.2</td>
<td>55.7</td>
<td>29.2:1</td>
</tr>
<tr>
<td>Wild pig</td>
<td>114.2</td>
<td>6.6</td>
<td>17.3:1</td>
</tr>
<tr>
<td>Deer+sambar+pig</td>
<td>3276.1</td>
<td>427.1</td>
<td>7.7:1</td>
</tr>
</tbody>
</table>

(2002)
The culling of the herbivore population by the predator, scavenging by other animals etc. According to this method of estimation, RNP-Block I should have only about 10 leopards. However, since leopards also feed on many small animals other than deer, sambar and wild pig (Eisenberg & Lockhart, 1972; Myers, 1976; Santiapillai et al. 1982; Sathyakumar, 1992), the supportable leopard density could be higher than that estimated by taking into account only the large herbivore biomass.

Myers (1976) points out that the leopard can maintain densities of 0.1 km\(^2\) in moderately suitable habitat, 0.2 km\(^2\) in favourable areas and perhaps even 1.0 km\(^2\) under exceptionally suitable conditions. Since RNP-Block I (especially the coastal region) is a favourable area for leopards with respect to prey density, suitability of prey, and suitability of habitat for hunting, the observed densities of 0.3 km\(^2\) in the coastal region and 0.07 km\(^2\) in the inner region do not appear to be excessive.

At the beginning of the century, Clark (1901) estimated that the leopard population in the island numbered 1660. His estimate was based on a density of 0.13 individuals per sq. mile (0.05 individuals km\(^2\)) in the forests, which covered about 50% of the land area at the time. The forest cover is now reduced to 20% of the land area and, more importantly, a substantial area of this forest comprises isolated patches that are not suitable for a population of predators using large ranges. Even the fairly large tracts of forest, except those in the protected areas, have been subjected to much illicit felling, habitat degradation and poaching of herbivores. The examination of the forest areas in Sri Lanka for size, type, isolation, availability of suitable prey species, human interference, etc. indicate that the area suitable for leopards is at present cannot be more than 10% of the land area (i.e. 6565 km\(^2\)). The estimate of the RNP-Block I leopard population cannot be extended to the rest of the areas inhabited by leopards for several reasons including the low prey densities, high human interference, etc. in the latter areas. Therefore, using the density estimate of Clark (1901) and that of 0.03

<table>
<thead>
<tr>
<th>Species</th>
<th>Biomass (kg km(^2))</th>
<th>RNP</th>
<th>WNP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elephant</td>
<td>711.1</td>
<td>217.2</td>
<td></td>
</tr>
<tr>
<td>Buffalo</td>
<td>983.1</td>
<td>73.4</td>
<td></td>
</tr>
<tr>
<td>Spotted deer</td>
<td>582.4</td>
<td>263.0</td>
<td></td>
</tr>
<tr>
<td>Sambar</td>
<td>347.1</td>
<td>135.0</td>
<td></td>
</tr>
<tr>
<td>Wild pig</td>
<td>26.6</td>
<td>8.1</td>
<td></td>
</tr>
<tr>
<td>Deer+sambar+pig</td>
<td>956.1</td>
<td>406.1</td>
<td></td>
</tr>
</tbody>
</table>

*Common leopard prey*
km² by Eisenberg and Lockhart (1972), it appears that the present leopard population in the country is unlikely to be more than about 300 individuals, less than one-fifth of the population at the turn of the century.

Eisenberg & Lockhart (1972) found two peaks in the frequency of sightings of leopards during day time in Wilpattu National Park, one from 0600 to 1000 hrs and the other from 1500 to 1830 hrs. Santiapillai et al. (1982) also found two such peaks, from 0700 to 1100 hrs and from 1500 to 2100 hrs, in RNP-Block I. The results of the present study (Fig. 4) agrees with both previous studies regarding the evening activity peak after 1500 hrs, 49.2% of the sightings in the present study being after 1600 hrs. The morning peak, however, lasted only until about 0900 hrs. The frequency of sightings from 0900 to 1500 hrs was only 13.2%.

Although the leopard is considered a nocturnal hunter in general, this situation appears to depend mostly upon the degree of human-leopard interaction. Myers (1976) points out that leopards tend to become exclusively nocturnal only when they feel insecure by day either due to human harassment or disturbance by predatory competitors. Although the peak visiting hours in RNP are in the morning before 1000 hrs and in the evening after 1500 hrs, the high frequency of sightings of leopards during these times indicates that they have become used to human presence (in vehicles) and feel secure from harassment. In fact, on several occasions, leopards were found lying down on the road during daytime, apparently undisturbed even when a vehicle came within 30 m of them (pers. obs.). Phillips (1984) states that the leopard is probably the least nocturnal of all wild cats of Sri Lanka.

Myers (1976) points out that because of the elusive nature of leopard behaviour, human activities such as poaching could have a serious effect in assessing the status of leopards in areas of such human interference. He points out that in some areas in which no leopards were sighted for several years, detailed studies have shown the presence of a small population.

The male to female ratio of 0.8:1 of leopards estimated in the present study is in contrast to that of 2:1 obtained by Santiapillai et al. (1982) for RNP-Block I. But these authors have estimated the sex ratio on the basis of direct observations, a method which in the present study gives a sex ratio of 1.2:1. Eisenberg & Lockhart (1972) also sighted leopard males twice as often as females in Wilpattu National Park, but they point out that this could be due to a greater boldness on the part of the males in coming out of hiding rather than a reflection of the true sex ratio. This is probably the explanation for similar observations in RNP.

Schaller (1967) reports a similar situation in the case of the tiger (Panthera tigris). Of 575 tigers that were shot in India at one time (time period unspecified), 384 were males and only 191 were females, a sex ratio of 2:1. However, he points out that the predominance of males among those killed could have been due to the observed greater boldness of males in approaching baits. In other instances in which the males and females were identified individually, the sex ratio varied from 1:1.2 to 1:5, always favouring females (Schaller, 1967).

Eisenberg & Lockhart (1972) also showed that in a captive breeding programme of leopards, thirty five cubs were born of which 29 survived and were not devoured, and those that survived had a sex ratio of 1:1.6 favouring females. The sex ratio favouring females in this instance may not be just a coincidence.
Leopards usually give birth to 1-3 cubs of which only 1-2 will survive (Phillips, 1984). However, Clark (1901) cited litter sizes as high as 7, although in such instances it is unlikely that more than 2 or 3 cubs would survive. In the captive breeding programme referred to earlier, 35 cubs were born in 17 litters, litter size ranging from 1-3, with an average size of two (Eisenberg & Lockhart, 1972). These observations agree well with the present observations of the number of the cubs accompanying their mothers.

The gestation period of the leopard has been variously given as 98 to 105 days (Crandall, 1964), 99 to 100 days (Sadlier, 1966; Eisenberg & Lockhart, 1972) and 92 days (Phillips, 1984). Cubs will start following the mother only when they are 4-6 months old (Muckenhirn & Eisenberg, 1973) and will do so until they become independent when they are about 18 months old (Bertram, 1979). Thus, an interval of 9 months can be expected between breeding and the first appearance of cubs accompanying the mother. Therefore, the cubs seen in September and October are probably from the litters conceived in the breeding peak of previous November and December. Similarly the cubs observed in March-May period would probably have been conceived in the breeding peak of the same period in the previous year.

Peak breeding during March-May and October-December (rainy seasons) will result in cubs being born in the dry seasons (July-September and February-March) (Fig. 6). During the dry seasons, prey species visit grasslands and waterholes more often from the scrub as the small waterholes within the scrub become dry, and are presumably easier to catch. This may be important for the female leopard since she cannot leave the new-born cubs undefended for prolonged periods of time.

The only other predator that may offer some competition to the leopard is RNP-Block I is the crocodile, two species of which, namely, the swamp crocodile (*Crocodylus palustris*) and the estuarine crocodile (*C. porosus*), inhabit the numerous waterholes. Their number appears to be around 300 in RNP-Block I and the former species may numerically exceed the latter by about 10:1 (pers. obs.).

Acknowledgements
We wish to thank Mr B.A. Muthubanda (Park Warden) and other park officials of the Ruhuna National Park for their help during this study, and Mr T.S.B. Alagoda of the Department of Zoology, University of Peradeniya for preparing the figures. Our special thanks are due to the wildlife guides of the park who very conscientiously made available to us their daily observations on leopards. We are greatly indebted to Prof. John F. Eisenberg of Florida Museum of Natural History, USA, and Dr Charles Santiapillai of Department of Zoology, University of Peradeniya for reading the manuscript critically and suggesting several valuable improvements.

References
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