

GAUR (*BOS GAURUS*) ABUNDANCE, DISTRIBUTION, AND HABITAT USE
PATTERNS IN KUIBURI NATIONAL PARK, SOUTHWESTERN THAILAND

by

Supatcharee Tanasarnpaiboon

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GAUR (*Bos gaurus*) ABUNDANCE, DISTRIBUTION, AND HABITAT USE
PATTERNS IN KUIBURI NATIONAL PARK, SOUTHWESTERN THAILAND

Supatcharee Tanasarnpaiboon, Ph.D.

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Advisor: John P. Carroll

Population status of gaur (*Bos gaurus*), a wild cattle, in most habitats where they are present, is still unknown. As the use of camera traps in wildlife studies are widespread, I developed photographic individual identification procedures and utilized encounter histories of gaur individuals from camera trap data to estimate gaur abundance and density using the spatially explicit capture-recapture analysis. The study was conducted at Kuiburi National Park, southwestern Thailand, comprised of dry evergreen forest, moist evergreen forest, and man-modified secondary forest during November 2013- January 2015. I conducted 71 direct observations in a savannah-like habitat area to observe the numbers, as well as the sex and age ratios of gaur. The maximum number of gaur per sampling occasion observed by direct observation was 89 gaur. The ratio of young to juvenile to adult was 1.6: 1.3: 1. The sex ratio was 1.7 females to 1 male. I also set up 56 camera trap locations for the total of 8,999 trap-nights to monitor gaur numbers and distribution. Camera traps captured 841 gaur encounters in 649 trap-nights at 41 locations. Both observation methods detected herds more frequently than solitary gaur. I identified 22 females (10 adults and 12 juveniles) and 44 males (33 adults and 11 juveniles) based on multiple horn characteristics, including shapes, coloration patterns, and corrugation patterns. The average adult density from photographic capture-recapture analysis was $2.5 \pm 1.7\text{SE}$ gaur/100 km² (95% CI = 0.8-8.2), yielding an adult abundance

estimate of $48.2 \pm 2.3\text{SE}$ gaur (95% CI = 45.1-54.5) living in the park during the study period. The total number of gaur calculated from the age ratio ranged from 198-239 gaur. Lowland areas with human-modified secondary forest habitats, dominated by grass patches, mineral licks, and reservoirs, have a high frequency of encounters and have greater concentration of gaur than the other zones, which are mainly composed of evergreen forests and are located in mountainous areas. This study is the first to apply photographic capture-recapture data to estimate the population density and abundance of a free-ranging ungulate in Thailand. The technique holds promise for conservation and management of threatened and endangered species that are inherently difficult to sample, but it still needs validation to improve the accuracy of population parameter estimates.

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CHAPTER 1

GENERAL INTRODUCTION

SYSTEMATICS OF GAUR

Gaur *Bos gaurus* is an ungulate, which describes hoofed mammals and includes all wild cattle species belonging to the superorder Cetartiodactyla. The order Artiodactyla contains even-toed ungulates, i.e., ruminants (Suborder Ruminantia), pigs (Suborder Suiformes), hippos (Suborder Ancodonta, and camels (Suborder Tylopoda). Wild cattle including gaur belong to Family Bovidae in Suborder Ruminantia. A distinguishing characteristic of members of Bovidae is their digestive system that is comprised of three or four stomach compartments with symbiotic interactions with cellulose-digestible microorganisms. The horns of Bovids are permanent bones covered with sheaths of keratin. Bovids are diverse with approximately 140 species and are prevalent across a large geographical distribution. Bovids are found on all continents except Australia, Antarctica, and South America. Bovids are sub-divided into three tribes, and gaur is a member of the tribe Bovini, consisting of cattle, bison, yak, buffalo and saola. In the most recent morphological classification, 13 species are listed as the members in the Bovini tribe (Hassanin 2014):

- 1) *Bos gaurus* C. H. Smith, 1827 – guar
- 2) *Bos javanicus* d'Alton, 1823 – banteng
- 3) *Bos mutus* (Przewalski, 1883 – yak
- 4) *Bos primigenius* Bojanus, 1827 –aurochs
- 5) *Bos sauveli* Urbain, 1937 – kouprey
- 6) *Bison bison* (Linnaeus, 1758) – American bison
- 7) *Bison bonasus* (Linnaeus, 1758) – European bison

8) *Bubalus arnee* (Kerr, 1792) – Asian buffalo

9) *Bubalus depressicornis* (C. H. Smith, 1827) – lowland anoa

10) *Bubalus mindorensis* Heude, 1888 – tamaraw

11) *Bubalus quarlesi* (Ouwens, 1910) – mountain anoa

12) *Pedudoryx nghetinhensis* Dung, Giao, Chinh, Touc, Arctander & MacKinnon, 1993 – saola

13) *Syncerus caffer* (Sparrman, 1779) – African buffalo

Based on measurements of skulls and horns, two subspecies of gaur have been proposed. *Bos gaurus gaurus* lives in India, Nepal, and possibly Bangladesh whereas the other subspecies, *Bos gaurus laosiensis*, is found in Southeast Asia (Myanmar, Lao PDR, Vietnam, Cambodia, Thailand and west Malaysia) and southern China. However, the dual classification is still inconclusive because the morphological measurements are based on only a few skull samples, and there is no supporting genetic analysis (Groves and Grubb 2011, Hassanin 2014). In some instances, *Bos frontalis* (Lambert 1804) has alternatively been used as the scientific name of gaur, however, the International Commission of Zoological Nomenclature (2003), in a recent review, decided to use *Bos frontalis* only for the mithun, a domestic form of gaur.

A gaur has a high ridge on the back and white or yellow stockings on all four legs. The forehead is grayish or golden due to oil secretion, down to the level just above the eyes (Figure 1.1). A unique feature of the gaur distinguishing them from other bovine species is the oily secretion on the males' skin, which has insect repellent properties (Tran and Chauhan 2007, Ahrestani and Karanth 2014). Newborn gaur are light orange-brown and change to black after 4-5 months. Gaur body mass ranges from 440 to 941 kg. Shoulder height ranges from 145 to 197 cm. The head and body

length ranges from 249 to 330 cm. Tail length ranges from 70 to 89 cm.

Morphological characteristics including horns, dorsal ridge, and muscularity are used to distinguish between males and females. Such morphological differences between sexes are visible after approximately 15 months. For example, females are not as stocky and muscular as males and have a thinner dorsal ridge. Female horns are much smaller, closer together, and pointed inwards (Lekagul and McNeely 1988, Ahrestani 2009). However, the secondary sexual traits, such as horn curvature, dorsal ridge, and muscularity are not conspicuous in the field until they reach adult age (greater than 3 years old). The estimated maximum longevity of both sexes is 25 years in captivity (Ahrestani 2009).

Gaur are social animals, and herds are a mixture of both sexes and multiple age classes. However, males may be observed as solitary individuals, or in small groups containing only males. Males also often compete to become the dominant male in the herd, especially during the breeding season (Lekagul and McNeely 1988, Prayurasiddhi 1997, Ahrestani and Karanth 2014). The timing of the annual mating and calving period varies among regions. For example, the mating season in a gaur population in central India was reported in December and January, yielding the calves in August and September (Dunbar-Brander 1923 in Ahrestani and Karanth 2014), whereas the peak rutting period of a southern India population was in November to March (Morris 1938 in Ahrestani and Karanth 2014). In Malaysia, young gaur were seen at all times except from October to December (Hubback 1937 in Ahrestani and Karanth 2014). However, recent study of a gaur population in India suggested that gaur do not have specific mating seasons because calves were seen throughout the year (Ahrestani and Prins 2011). The gestation period is approximately 9-10 months (~ 280 days). Female gaur become sexually mature at the age of three years and have

been shown to reproduce at the age of 18 years in captivity (Ahrestani 2009, Ahrestani and Karanth 2014).

GAUR BEHAVIOR AND ECOLOGY

Gaur is assumed as a nocturnal animal. They start foraging at dusk in the open areas, which provide grasses, but gaur rest and sleep almost all day in the forest until dusk. They browse on any edible leaves and young green grass. The mineral salt is also necessary for the gaur but is rarely used in dry seasons when the soil dries out. Water is also a crucial resource for gaur (Conry 1981, Lekagul and McNeely 1988, Bidayabha 2001, Ahrestani and Karanth 2014).

Gaur inhabit forests of all elevations up to 2,800 m. Habitats utilized by gaur vary by season, influenced by food and water availability. Deciduous forests and grassy openings are often used during the wet season. In contrast, they move towards evergreen forest and hilly terrain to seek forage and water during the dry season (Schaller 1967, Steinmetz 2004, Ahrestani 2009, Melletti and James Burton 2014). They eat a wide variety of vegetation, including bamboos, grasses, herbs, shrubs, vines, tree bark, and fruits. They are considered grazers but shift to browse other plants during drier periods, when grasses and bamboos are scarce (Prayurasiddhi 1997, Steinmetz 2004, Gad and Shyama 2011, Ahrestani et al. 2012). Multiple factors, such as forest types, humidity, elevation, food availability, and anthropogenic pressures may result in changes of gaur social behavior and habitat utilization patterns in both space and time (Bhumpakphan 1997, Piyapan 2000, Steinmetz 2004, Ahrestani et al. 2012). They have been reported to only inhabit the remote forested areas that are far from human activity (Lekagul and McNeely 1988, Bhumpakphan 1997). However, many recent studies have suggested that gaur can adapt to human-

disturbed habitats. For example, they frequently forage near forest edge habitats and in regenerating forests such as Khao Phaeng Ma in eastern Thailand, Kuiburi National Forest Reserve in southwest Thailand (Bidayabha 2001, Department of National Parks Wildlife and Plants Conservation 2010), and near agriculture areas in Lepar Valley, Pahang, Malaysia (Conry 1989). Their habitat use patterns also depend on sex and social structure (Conry 1989, Prayurasiddhi 1997, Steinmetz et al. 2008). In a study of the large mammal community in the Tenasserim-Dawna Mountains, Thailand, solitary bulls prefer montane forest (>1000 m elevation), while guar herds prefer mixed deciduous and semi-evergreen forest in lowlands (<1000 m elevation), which provides high quality food for gestation and lactation. Bulls use montane forest even though they contain lower-quality forage because dense habitats in montane forest may offer a refuge for bulls to avoid hunting by humans (Steinmetz et al. 2008).

Gaur are one of many prey species for large predators, especially tigers *Panthera tigris*, leopards *Panthera pardus*, and dholes *Cuon alpinus* (Schaller 1967, Karanth and Sunquist 1995, Karanth and Stith 1999, Ngoprasert et al. 2012). Studies of predator-prey interactions in Kuiburi National Park showed that an increase in the presence of tigers was positively related to predation occurrences on gaur (Steinmetz et al. 2009). Other studies of the tiger-prey relationship in India also demonstrated that gaur contribute a large portion of prey biomass for the tiger in India (Karanth and Sunquist 1995, Ahrestani 2009). The benefits of prey population recovery should maintain and increase predator populations (Karanth and Stith 1999). However, the consequences might also be negative for local villagers at the forest edge. In areas with a high density of gaur such as Indian subcontinents, crop raiding by gaur is intense and some reports exist on human injury or death by gaur attacks (Manoj et al. 2013, Prashanth et al. 2013).

Large herbivores, such as gaur, influence the plant community like landscape architects. Their foraging behaviors and movements might cause habitat modification, which facilitate seed germination and influence mortality of plants at various degrees (Ahrestani and Karanth 2014). They require a large amount and variety of plants to forage to meet the metabolic requirement of their large body size. In addition, because gaur forage on many plant forms, including fruits, they also are potential seed dispersers (Corlett 1998).

GAUR DISTRIBUTION, POPULATION STATUS, AND THREATS

WORLDWIDE AND IN THAILAND

Gaur are distributed from the Indian peninsula to as far north as Nepal and east throughout mainland Southeast Asia (Figure 1.2) (Lekagul and McNeely 1988, Melletti and James Burton 2014). Their conservation status on the IUCN Redlist is listed as Vulnerable, with the estimated global population of 13,000-30,000 animals (Duckworth et al. 2008). It is now assumed that no single area has a population >1,000 individuals. Hence, the global trend in abundance has generally suggested declining populations likely due to population fragmentation from habitat loss and poaching for meat (Choudhury 2002, Duckworth et al. 2008). Even in the Indian Subcontinent, which is home to the largest gaur population, the population is highly fragmented and most subpopulations are not viable populations as a result of reduced meta-population connectivity (Choudhury 2002).

In Thailand, gaur are reported in 45 protected areas including 25 national parks and 21 wildlife sanctuaries as shown in Figure 1.3 (Department of National Parks Wildlife and Plants Conservation 2010). Srikosamatara and Suteethorn (1995) estimated that the total population size of gaur in Thailand based on various secondary

sources and short term field surveys in several national parks was 915 individuals inhabiting only 14 protected areas. Half of the gaur in Thailand was in the Western Forest Complex (WEFCOM), including Huai Kha Khaeng Wildlife Sanctuary and Thung Yai Naraesuan Wildlife Sanctuary, and the other populations scattered in other forest complexes (Figure 1.3). Gaur populations in much of Southeast Asia region have generally decreased due to poaching for trophies, habitat loss and fragmentation, and effects of human encroachment in forested habitats for settlement and agriculture (Heinen and Srikosamatara 1996, Ahrestani and Karanth 2014). In contrast, gaur populations in Thailand have increased in abundance. For example, the abundance estimates of gaur in Thung Yai Naraesuan Wildlife Sanctuary, western Thailand from tracks and signs indicated that the abundance indices of gaur gradually increased by three times over the six year study during 1999-2005 (Steinmetz et al. 2010). The prey surveys in Kuiburi National Park, southwestern Thailand, in 2006 and 2009 indicated a positive tendency in gaur occurrence and abundance (Steinmetz et al. 2009). The same trends also appeared in the other regenerating forests or buffer areas formerly utilized by humans such as Khao Phaeng Ma Forest Reserve which is contiguous to Dong Phrayayen-Khao Yai Forest Complex (Figure 1.3) (Bidayabha 2001).

In Thailand, most of the biodiversity is restricted to protected areas, and conservation actions of natural resource management are primarily implemented in such areas. However, forested areas are still continuously encroached upon by human settlement and agriculture. Forested areas in Thailand have declined from 43 % of the country's area in 1973 to 31% in 2013 (Department of Forestry 2013). Small and fragmented gaur populations, due to shrinking available habitats, increase vulnerability of gaur persistence. For instance, gaur might have to confront threats associated with small and declining population size, including inbreeding pressures

(Lacy 1997) and disease outbreaks (Woodroffe 1999). In addition, gaur inhabiting edge habitats, might more frequently be exposed to human threats, including poaching, being killed when raiding crops, and contagious diseases from domestic cattle.

KUIBURI NATIONAL PARK, THAILAND

Kuiburi National Park ($11^{\circ} 40' - 12^{\circ} 10' \text{ N}$ and $99^{\circ} 20' - 99^{\circ} 50' \text{ E}$) is located in Prachuap Khiri Khan Province in southwestern Thailand (Figure 1.4). It is a part of the Kaeng Krachan Forest Complex, which is in the Tennesarim range. It was established in 1999 and covers 969 km^2 . It is a mosaic between forested and human-utilized habitats. The central part of the park is comprised of dry evergreen forest and managed-secondary forest under the Royal-Initiated Kuiburi National Forest Reserve Project (also called as 'Payang' or 'Khunchorn Project'). The northern side of the park is contiguous to a military protection area, which is an ecological corridor between Kaeng Krachan National Park and Kuiburi National Park. Those areas will be officially included in the park and the total park area will become $1,057 \text{ km}^2$.

The climate is tropical savannah with a pronounced dry season and long wet season (Figure 1.5). Seasons can be divided into three. Rainy season starts from May to November (7 months). The cooler dry season is from December to February (3 months). The rest of the year, March to mid-May, is the hot season influenced by occasional tropical monsoons (Temchai et al. 2010). The highest temperature occurs in the months of April and May, in which temperatures can reach to 37°C . The lowest temperature occurs in December and January, in which temperatures can be as low as 18°C . Average annual precipitation in Prachuap Khiri Khan Province from 2009 to 2013 is 918 mm (ranges 793-1418 mm) with the average of 131 rain days