



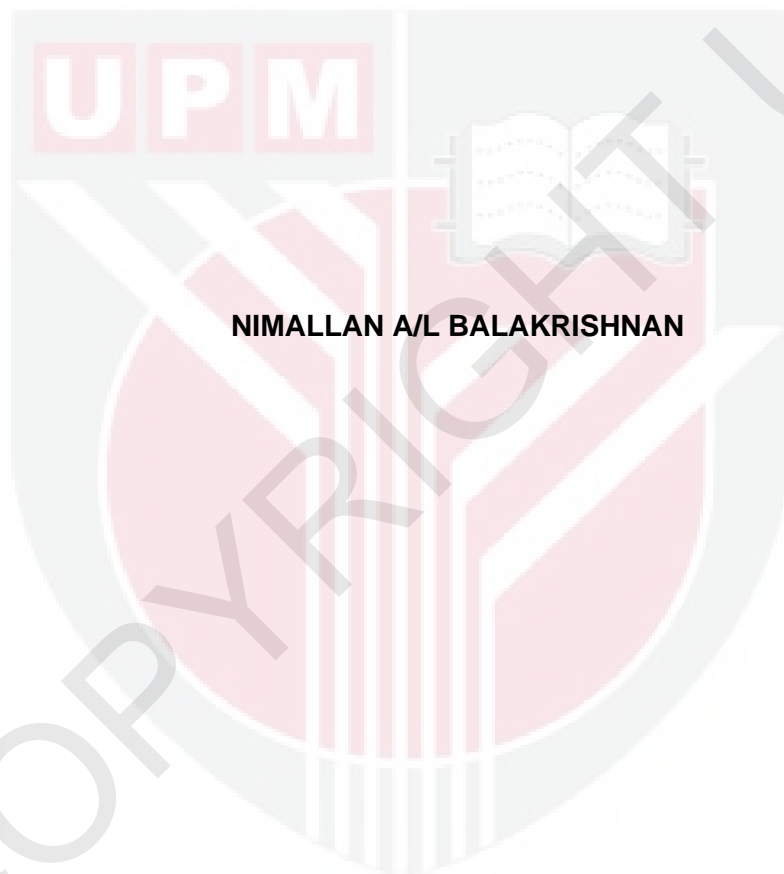
**UNIVERSITI PUTRA MALAYSIA**

**SEXUAL BEHAVIOUR DURING BREEDING PERIODS IN MALAYAN  
TIGER AT THE MALAYAN TIGER CONSERVATION CENTRE,  
LANCHANG, PAHANG.**

**NIMALLAN A/L BALAKRISHNAN**

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FPV 2022 44**

**SEXUAL BEHAVIOUR DURING BREEDING PERIODS IN MALAYAN TIGER AT  
THE MALAYAN TIGER CONSERVATION CENTRE, LANCHANG, PAHANG.**



**NIMALLAN A/L BALAKRISHNAN**

A project paper submitted to the  
Faculty of Veterinary Medicine, Universiti Putra Malaysia  
In partial fulfilment of the requirements for the  
DEGREE OF DOCTOR OF VETERINARY MEDICINE  
Universiti Putra Malaysia  
Serdang, Selangor Darul Ehsan.

**DECEMBER 2022**

## **CERTIFICATION**

It is hereby certified that we have read this project paper entitled “Sexual behaviour during breeding periods in Malayan tiger at Malayan Tiger Conservation Centre, Lanchang, Pahang”, by Nimallan A/L Balakrishnan, and in our opinion, it is satisfactory in terms of scope, quality, and presentation as partial fulfilment of the requirement for the course VPD 4999 – Final Year Project.

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## **DEDICATION**

This thesis is dedicated to my:

**God**

**Beloved family**

**Supervisor**

Dr Wan Nor Fitri Bin Wan Jaafar

**Co-supervisors**

Dr. Tengku Rinalfi Putra Tengku Azizan

Pn. Hartini Ithnin

En. Mohammad Khairi Ahmad

**My friends**

Sorga Vaasal

**My seniors**

Dr Sreetharan

Dr Kirtanah Selvi Selva Nathan

**Athan, Squash, Queen (MTCC Tigers)**

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Heartfelt thanks to you Aiman Murad, my FYP mate for accompanying and supporting me both physically and emotionally throughout my final year project journey. I would like to recognise and thank Masters students at the FPV Theriogenology Laboratory, Dr Husna and Mr Vijay for continuously guiding, following me to the project site and aiding me. A special thanks to Dr Sreetharan for guiding me with his previous FYP experience with tigers and my buddies Dr Kirtanah and Dr Aravinthan for their assistance, guidance, and support to me when it came to project documentation and completion. I am also appreciative of my DVM23 batchmates for their kindness, thoughtfulness and for working together as one team and being there for each other always.

The support, encouragement, and strength I received from my dear comrades of Sorga Vaasal, including VETERNAK VIC Hicom, Arvinderan and Ravenia, is

immense and endless. I would also like to acknowledge my friends, Raadhika, Haritharan, Kuhan, Prasant, Mogeneswary, Navalaxmi, Thirshamytra, Kausalya, Jaganathan and Vikineswaran, for their endless motivation and support. Thank you for always being there for me, hearing my pleas and helping me get through my final year project as well. This endeavour would not have been possible without my parents, my sisters, Pavitra and Sujitra, newlywed brother-in-law, Pravin and Amuma, for they have given me their full support, encouragement, unconditional love, care, advice, and motivation to complete my FYP successfully.

Last but not least, I would like to thank God for always giving me strength and motivation, just by remembering Her. It is She who was the inspiration behind my study and guided me towards and throughout it. Thank you for being there for me when I faced hard times and needed it the most. All of you mean the world to me and this project will not have been a success without all of you. Thank you from the bottom of my heart to everyone who was involved directly or indirectly in this project.

*The tiger perishes without the forest, and the  
forest perishes without its tigers. Therefore the  
tiger should stand guard over the forest, and the  
forest should protect all its tigers.*

Mahabharata (about 400 BCE)

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## **ABSTRAK**

Abstrak daripada kertas projek yang dikemukakan kepada Fakulti Perubatan Veterinar untuk memenuhi sebahagian daripada keperluan kursus VPD 4999 –Projek Tahun Akhir.

### **Sifat seksual harimau Malaya semasa tempoh pembiakan di Pusat Konservasi Harimau Kebangsaan, Lanchang, Pahang**

by

**Nimallan A/L Balakrishnan**

**2022**

**Penyelia: Dr. Wan Nor Fitri Bin Wan Jaafar**

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**Pn. Hartini Ithnin**

**En. Mohammad Khairi Ahmad**

Harimau Malaya (*Panthera tigris jacksoni*) terancam secara kritikal dan sebagai langkah keselamatan bagi menangani keadaan tersebut, program pemuliharaan pembiakan amat diperlukan. Sebelum memulakan program tersebut, suatu penyelidikan mengenai tingkah laku reproduksi yang teliti dan jelas harus dilakukan bagi memahami dasar fisiologi harimau Malaya. Titik kejayaan program pembiakan ini terbatas disebabkan pengetahuan keatas biologi spesies harimau sangat jarang dijalankan. Kajian ini bertujuan untuk mewujudkan tahap tingkah laku reproduksi harimau Malaya melalui pemerhatian tingkah laku seksualnya. Jantan yang belum matang secara seksual dan betina *P. t. jacksoni* yang matang secara seksual di Pusat Konservasi Harimau Kebangsaan, Lanchang, Pahang telah dipilih untuk proses pemerhatian ini. Sebuah kamera telah dipasang di dalam kurungan untuk merakam tingkah laku seksual dari 0930 hingga 1630 selama 14 hari. Kemudian, rakaman dianalisis menggunakan kaedah pemerhatian haiwan secara fokus berterusan.

Penemuan direkodkan pada etogram yang disesuaikan berdasarkan tingkah laku pembiakan seperti mundar-mandir (P), golean sosial (SR), pemupukan (PR), gesekan (R), jilatan anogenital (A), semburan penanda aroma/kencing (US), pencakaran (C), tindak balas Flehmen (F) dan panggilan seksual (CW). CW serta SR tidak diperhatikan dan kekerapan tingkah laku jantan AS, C, F, PR dan R setiap hari selama 14 hari kurang dari 1%. Walaubagaimanapun, fluktuasi dalam frekuensi telah diperhatikan pada betina. Peratusan min tingkah laku seksual adalah  $9.93 \pm 6.92$  selama 14 hari. Secara ringkasnya, tingkah laku yang disenaraikan di atas merupakan petunjuk pembiakan yang baik terutama dalam menentukan kematangan seksual harimau. Dalam pada masa yang sama, sifat mundar-mandir harimau Malaya dikecualikan kerana dipercayai sebagai tingkah laku stereotaip.

**Keywords:** Harimau Malaya (*Panthera tigris jacksoni*); reproduksi; pemerhatian jauh; estrus; terancam secara kritikal.

## **ABSTRACT**

An abstract of the project paper presented to the Faculty of Veterinary Medicine in partial fulfilment of the course VPD 4999 – Final Year Project.

### **Sexual behaviour during breeding periods in Malayan tiger at Malayan Tiger Conservation Centre, Lanchang, Pahang.**

by

**Nimallan A/L Balakrishnan**

**2022**

**Supervisor: Dr Wan Nor Fitri Bin Wan Jaafar**

**Co-Supervisors: Dr.Tengku Rinalfi Putra Tengku Azizan**

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The Malayan tiger (*Panthera tigris jacksoni*) is critically endangered and as an insurance measure to less than 150 wild tiger populations, a conservation breeding programme is deemed necessary. Before this, well-defined research on reproductive behaviour relationships should be done to understand the basics of reproductive physiology in the Malayan tiger. The success of the breeding programme for the Malayan tiger has been limited, with knowledge regarding this species' reproductive biology remaining scarce. This study aims to establish the standard reproductive behaviour of the Malayan tiger through sexual behaviour observations. One sexually immature male and one sexually mature female *P. t. jacksoni* at Malayan Tiger Conservation Centre (MTCC), Lanchang, Pahang were selected. Cameras were set within the enclosure to record sexual behaviours from 0930 to 1630 for 14 days. Footages were analysed using the focal animal continuous sampling observation

method. The findings were recorded on a customized ethogram based on reproductive behaviours like pacing (P), social roll (SR), prustening (PR), rubbing (R), anogenital groom (A), scent-marking (US), clawing(C), Flehmen's response (F) and caterwaul (CW). No CW and SR were noticed and the daily frequency of US, C, F, PR and R behaviours in the male over 14 days were less than 1%. Nevertheless, synchronous fluctuations in the frequency of different magnitudes were noticed in the female. The mean percentage of sexual behaviours was  $9.93 \pm 6.92$  of the total calculated slots over 14 days. In short, the behaviours listed above are good reproductive indicators especially when it comes to determining the sexual maturity of the tigers. Pacing is likely, an exception as it could be stereotypical behaviour.

**Keywords:** Malayan tiger (*Panthera tigris jacksoni*); reproduction; remote observation; estrous; critically endangered.

## 1.0 INTRODUCTION

The Malayan tiger (*Panthera tigris jacksoni*) is very valuable to our country and wildlife community as it is known as the specific subspecies native to Peninsular Malaysia (Kawanishi et al., 2003, 2010). It is an iconic umbrella species that are important in safeguarding the tropical rainforest ecosystem. The Malayan tiger is an important part of identity for Malaysia as it is also a symbol of pride and courage. Malaysia has adapted the value of the tiger as we named the Malayan tiger our national animal. The Malayan tiger has been used as part of the insignia in the national coat of arms, emblems of the Royal Malaysia Police, Maybank, Proton and the Football Association of Malaysia.

However, this species is on the verge of extinction in the wild as a critically endangered species within the next decade. With 150 individuals that are estimated to be left in isolated and fragmented rainforest habitats throughout Malaysia (Ten et.al., 2021), it is important to prevent the further loss of valuable animals through conservative medicine to protect their population. Conservation of tigers can be done by assisted reproductive technique (ART) rather than natural breeding due to the higher success rates (Donoghue et al., 1993). Before ART can be successfully implemented, a fundamental understanding of the reproductive relationships with physiology and ethology should be established in the Malayan tiger. Tigers, originating from the Felidae family have a unique and slightly deviated estrous cycle from other species; they are induced ovulators where frequent mating is needed for ovulation. Moreover, they are photoperiod-synchronised seasonally polyestrous species, making them breedable all year long (Brown, 2018).

The estrous cycle of a tiger lasts for 4-5 weeks while estrus, indicated by peak estradiol lasts for 3-10 days. They go through a short interestrus phase but when ovulation induced by multiple copulations is successful but unsuccessful fertilization, they undergo a non-pregnant luteal phase. But to our interest, behavioural estrus is seen together with peak estradiol. To understand the changes in behaviour on estrous cycles, daily or almost daily records are necessary (Crockett et.al., 2010). Although visual observation analyses can be difficult to interpret and have issues with consistency and reliability, it is important to investigate the potential due to the non-invasive nature of the technique and easy accessibility to obtain the data.

Thus, Malayan Tiger Conservation Centre, Lanchang, Pahang was deemed suitable for this study as this facility visions to lead the preservation, research, and conservation of the Malayan tiger to become an international centre of excellence. Objectives of MTCC also consist of carrying out natural or ART breeding programs to increase the stock population of Malayan tiger in captivity, rewild them by preparing rehabilitation facilities and release them back into identified suitable locations in the wild.

## **1.1 OBJECTIVE**

General objective:

To identify and analyse the reproductive behaviour of the Malayan tiger in captivity

**Specific objectives:**

1.1.1 To establish the standard reproductive behaviour of the Malayan tiger through sexual behaviour observations

1.1.2 To establish reproductive behaviour in the male tiger as it reaches puberty

## **1.2 HYPOTHESIS**

Null hypothesis (H<sub>0</sub>): The sexual behaviour observation of male and female tigers cannot determine puberty

Alternate hypothesis (H<sub>1</sub>): The sexual behaviour observation of male and female tigers can determine puberty.

## **1.3 JUSTIFICATION**

Well-defined research on reproductive behaviour relationships has been limited, with knowledge regarding this species' reproductive biology remaining scarce since most papers published are on Siberian or Sumatran tigers. This helps to identify the reproductive behaviour for a safe and successful pairing between the male and female tiger.

## 2.0 LITERATURE REVIEW

### 2.1 MALAYAN TIGER

*Panthera Tigris*, 1758 (once known as *Felis Tigris Linnaeus*) are the largest species of the Felidae family in Order Carnivore, found only in Asian continents (Department of wildlife and national Parks, 2008; Goodrich et al., 2015). It can be recognized by having black and white vertical stripes on orange fur (Kitchener & Yamaguchi, 2010). For more than two and a half centuries, the tiger is found incomparable for its wildness, magnificence, and ferocity. As mentioned by Christie (2010), the beast has a never-ending complicated relationship with humanity. Liu et al. (2018) reported as early as the first half of the 19<sup>th</sup> Century the first subspecies, Caspian Tigers *P. t. virgata* was discovered through intraspecific molecular genetic taxonomy. Nevertheless, the first divergence of subspecies dates back more than 50,000 years which were Bengal Tigers *P. t. tigris* whereas the latest were Amur Tigers *P. t. altaica*(Liu et al., 2018).

*Panthera tigris subspecies jacksoni*, 2004, commonly known as Malayan tiger is the smallest subspecies with an average size of 2.4m long and weighs up to 120kg (Department of wildlife and national Parks, 2008; Kawanishi et al., 2010). *P.t. jacksoni* from ancient *P.t. corbetti* occurred during the start of the Last Glacial Maximum that led to isolation on the Malayan Peninsula, south of the Isthmus of Kra from Indochinese counterpart on Sundaland and are thought to number fewer than 500 (Goodrich et al., 2015; Liu et al., 2018). The Indochinese tiger is the sister, monophyletic taxa to the Malayan tiger, with a recent yet significant differentiation (Kawanishi et al., 2010; Liu et al., 2018).

## **2.2 DISTRIBUTION AND POPULATION OF MALAYAN TIGERS**

With only fewer than 150 individuals in the wild, it is classified as Totally Protected under the Wildlife Conservation Act 2010 (Takiyuddin, 2022). Tilson et al. and Kawanishi suggest that Malayan tigers are widely distributed among larger tropical rainforest blocks, mangrove swamps, peat swamp forests and surprisingly even non-forested lands including riverine woodlands, belukar (early-succession brushwood), abandoned fields and agricultural lands. Loss of habitat due to rapid agricultural expansion could be the most logical reason for their inhabitant even abandoned fields and agricultural lands. Geographically, they are now landscaped in Main Range to the west, which includes Taman Negara National Park and surrounding permanent reserved forest to the east (Kawanishi et al., 2003, 2010). TIGER CONSERVATION ISSUES (2008) by PERHILITAN indicates that Malayan tigers still exist in the states of Pahang, Perak, Kelantan, Johor and Terengganu only.

Back in 2003, there were around 500-1,500 tigers nationwide in the wild, excluding tiger cubs or those living in other non-forested lands (Kawanishi et al., 2003). Having lost over 95% of natural habitat throughout Asia as development increases, the small, fragmented population in non-forested land are likely to have disappeared. According to TIGER SSP – Tiger Conservation Campaign by AZA, Malayan tiger is in Yellow Species Survival Programme as Critically Endangered under the IUCN Red List for Threatened Species.

## **2.3 REPRODUCTION**

Reproduction is key to this species' survival as Panthera species proliferate well in captivity, and hormones drive this process. Thus, understanding the basic

reproductive physiology and endocrinology of felids is vital for their conservation and management. (Brown, 2011).

### 2.3.1 REPRODUCTIVE PHYSIOLOGY

Tigers are suggested to be induced ovulators since frequent mating is normal in these non-domestic felids, as shown in Figure 1 (Brown, 2018). Due to the broad distribution over diverse climatic regimes, both wild tigers and those in captivity are adapted to seasonal polyestrous reproductive patterns, which may be synchronized by photoperiodicity that likely involves control of melatonin (Brown, 2011, 2018; Tilson et al., 2016). Yet, Putranto (2011) contradicts this statement by stating that wild tigers in the wild can breed all year long and there are non-existent or rare records of spontaneous ovulators which is indicated by spontaneous progestogens increasing post estrogen surges.

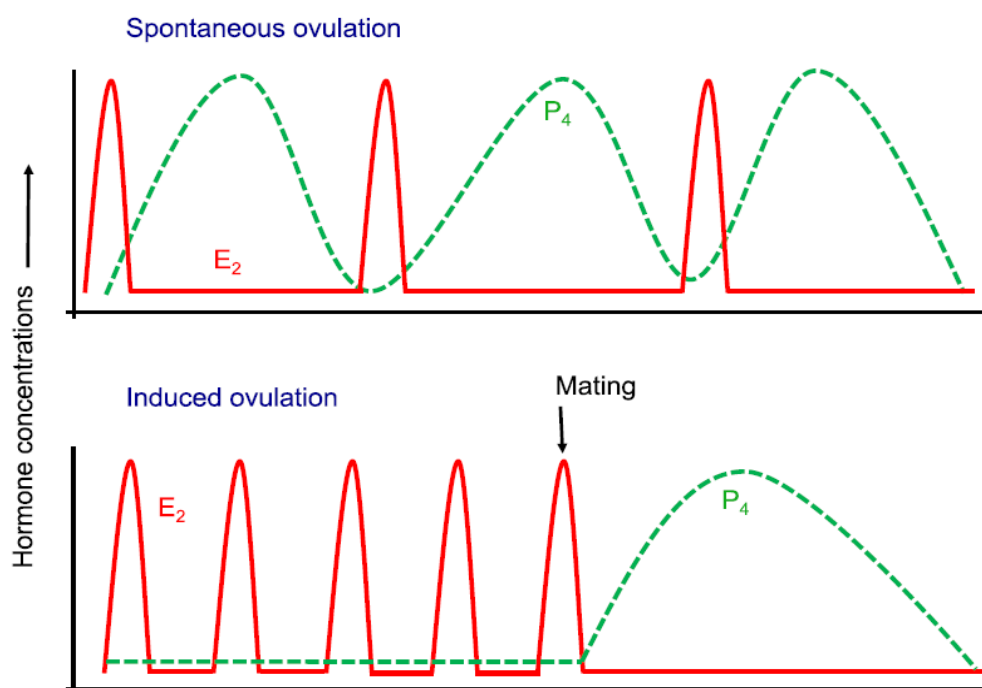


Figure 1. Schematic demonstrating spontaneous (top panel) and induced (bottom

panel) ovulation patterns of estradiol (E2, red line) and progesterone (P4, dashed green line).

*Note.* Retrieved from Comparative ovarian function and reproductive monitoring of endangered mammals, by Brown J. L., 2018, Theriogenology, 109, pg5

Generally, there are four phases of the felid estrus cycle which are proestrus, estrus, diestrus and anestrus (or interestrus), a result of a cascade of changes in the hypothalamic-pituitary-gonadal axis. Proestrus is related to the presence of ovarian follicles, surging circulating estrogens which last less than a day (Tilson et al., 2016). Estrus is indicated by advanced follicular development and peak estradiol concentration and correlated with behavioural estrus (Brown, 2011, 2018; Tilson et al., 2016). This causes final oocyte maturation for ovulation upon mating. Diestrus is the phase of elevated progesterone due to the presence of one or more corpus luteum. The longest period of low levels of circulating estrogen as follicular growth is known as anestrus (Brown, 2011). Janine L. Brown (2011, 2018) ultimately states that the estrous cycle is expected to last for 4 – 5 weeks and estrus lasts for 3 – 10 days. Inter-estrous intervals period that follows estrus in a queen that has not been induced to ovulate by copulation. In queens that have not copulated, no ovulation occurs and no corpora lutea form. Therefore, neither metestrus (CL formation) nor diestrus occurs. As in most induced ovulators, it would be appropriate to consider that the female would remain in a constant follicular phase until copulation occurs. After copulation, the female ovulates and only then does corpora lutea form. In this context, induced ovulators constitute a special form of the estrous cycle that does not have a true luteal phase. Tigers are generally around 18 – 28 Days ( $\pm$  12 days) (Tilson et al., 2016). Gestation in tigers is roughly about 104 – 108 days and the non-pregnant luteal phase is  $34.5 \pm 1.85$  days It is observed that subspecies-specific variation in

reproductive patterns, pointing out the necessity to consider them independently for conservation goals (Tidière et al., 2021).

### 2.3.2 PUBERTY / SEXUAL MATURITY IN MALE & FEMALE

Based on Sunquist, 1981 and Viau et al., 2020, it could be deduced that prepubertal starts at an estimated 20 – 30 months of age with apparent behavioural changes on the 30<sup>th</sup> month of age. Even after initiating ovarian cycling at 20 months, female wildcats may show inconsistent cycles and behaviour for an extended period. In a study during this period, a female was distanced from a male of similar age at  $5.0 \pm 0.4$  km with 90% of the occurrence being more than 1.6km (Sunquist, 1981). Nevertheless, in captivity, variation in normal sexual maturity is set to be seen. For example, copulation has been observed as early as 2.5 years and yet there have been cases of sexual maturity at 5 and 6 years (Das, 1981). An apparent behaviour change can be seen due to sexual maturity which attracted the male (Sunquist, 1981).

For domestic cats, puberty is indicated by first sperm ejaculation and penile spines (Root, 2009). Penile spines are cornified papillae, encircling corpus cavernosum glandis which are known to be androgen-dependent (Senger, 2012). In the case of tigers, penile spines are indicators and possible reasons for the tigress to lash out and snarl at the male. This is because it scrapes the inside of the female's vagina when removed. This scraping has 2 purpose which is to remove any old sperm from rival males and helps to induce ovulation by stimulating the walls of the vagina (Brooke, 2020). Male sperm has the potential of fertilizing the egg of the female due to this anatomical feature and repeated mating (Brooke, 2020; Senger, 2012).

### 2.3.3 REPRODUCTIVE BEHAVIOUR

#### 2.3.3.1 FEMALE REPRODUCTIVE BEHAVIOUR

Based on Seal et al. (1987) study on behavioural profile, behaviour is reported as an almost quantitative indicator of estrus in females. Frequencies of those behaviours showed a strong correlation with endocrinological surges and drops in hormone levels stated above. Examples are vocalization, prustenng, rubbing against the walls and bars of enclosure, social roll, and lordosis/semi-lordosis. Writhing on the back and semi-exclusively, Flehmen's response to the pacing which are correlated to a surge in estrogen hormone (Brown, 2011; Sunquist, 2010; Tilson et al., 2016). Based on Das (1981) and Mountfort (1973) findings, periods of play and social roll, harmless sparring and lordosis (lies on the belly, forelimbs fully stretched and hind-limbs half bent) are primary signs of estrous behaviour. Prelude to that, chuffing, pacing due to restlessness and Flehmen's response could be seen as secondary signs (Das, 1981). Urine spray is a common secondary behaviour between and after estrus periods, and yet it is often seen at increased frequency in hand-reared free-living tigress in unfamiliar terrain in captivity. Tigress that has reached puberty has notably more caterwauling than sexually experienced ones (Sunquist, 1981; Viau et al., 1981). Even anestrus is characterized by complete apathy, silence and constant resting of females (Tilson et al., 2016). These indices help in the timing of the seasonal separation of pairs as tigers are solitary animals and housing two individuals that are sexually unreceptive can be deadly (Brown, 2011; *TIGER CONSERVATION ISSUES*, 2008).

#### 2.3.3.2 MALE REPRODUCTIVE BEHAVIOUR

Understanding male reproductive behaviour and related physiology are equally important in the context of captive breeding of endangered wildlife species (Kamgang

et al., 2020; Rasmussen et al. 2008). Unfortunately, many breeding programmes have contributed to female reproductive physiology and performance but a full overview of an organism's biology is required, along with a thorough understanding of its reproductive aspects. The majority of mammal reproductive activity is controlled by environmental variables or circadian rhythm affected by a particular zeitgeber or entrainer which in this case is the female (Kamgang et al. 2020). Felids' photoperiod-induced seasonality is regulated by melatonin which is a zeitgeber that keeps biological clocks in synchrony with the day–night cycle (Breed, 2017; Brown, 2011). It is known that androgen is a great indicator of reproductive status, aggression, social status and sexual behaviour in male ungulates, white rhinoceros and male roan antelope (Kretzschmar et al., 2004; Rasmussen et al., 2008). Sexual behaviour in male tigers includes pacing, flehmen's response, pelvic thrust, clawing, treading and scent marking (Kamgang et al., 2020; Tilson et al., 2016). Tommasi et al. (2021) state that males tend to show more Flehmen's response than females. This behaviour is a close-range investigative behaviour to volatile substances called pheromones (Senger, 2012). The vomeronasal olfactory system is the detector of semiochemicals from urine or mucous. (Tommasi et al., 2021). On the other hand, clawing is believed to be originated from tree scratching in the wild which serves as attention through disturbance of substrate and olfactory visual signal (Sunquist, 1981).

#### 2.3.4 REPRODUCTION AND STRESS

Reproduction in captivity is an argument that needs to be addressed, seeing the conservation efforts taken for endangered species, especially the Malayan tiger. Captive animals are subjected to stress due to unavoidable interaction with humans (both visitors and husbandry management) which vary from the environments they

used to live (Kamgang et al., 2020; Sherwen & Hemsworth, 2019). To cope, their reproductive rate is affected, resulting in genetic and phenotypic divergence between captive and wild individuals (Mcphee & Calrstead, 2010; Abdul Hamid et al., 2022).

The role of stress in population deterioration might be multifactorial and not clearly understood. Studies in male African elephants showed the strong interaction between the hypothalamic-pituitary-adrenal and -gonadal axis in predicting the signals linked to sexual behaviour suggesting a combined proximate function of these axes in deciding shifts. Bhattacharjee et al. (2015) stand that the interaction of the two hormones in determining signal presence which led to an apparent positive connection between androgens and glucocorticoid is the result of glucocorticoid's suppressive influence on signal presence. This could be the effect of the local external competitive environment and the occurrence of receptive females (Rasmussen et al., 2008). Similar positive associations were found in another study by Brown et al. (2007), which was viewed as "potential involvement for the adrenal gland in modifying or promoting downstream response". Prolonged stress could be a negative influence on the hypothalamic-pituitary-gonadal axis as Tilbrook et al. (1999) report that a high concentration of glucocorticoids can inhibit gonadotropin secretion (Bhattacharjee et al., 2015).

## **2.4 CHALLENGES AND IMPORTANCE OF EFFECTIVE CONSERVATION IN CAPTIVITY**

The Malayan tigers, *P.t. jacksoni* is on the brink of extinction and has been classified as Critically Endangered under The IUCN Red List of Threatened Species (Version 2015.2). Luckily, one of the first few taxa to have their own managed breeding programme in zoos are tigers since they are relatively easy to manage and do not

establish monogamous relationships or social groups with complex hierarchical structures, which could make animal transfers and breeding more difficult (Christie, 2010; Traylor-Holzer, 2010). Nevertheless, one of the additional risks to small populations in captivity is increased vulnerability to demographic randomness and enrichment value of social housing in survival and reproduction that are likely to have an on-population persistence (Szokalski et al., 2012; Traylor-Holzer, 2010). It has been recorded that roughly half of all unsuccessful SSP breeding recommendations are due to tiger health concerns or behavioural discordancy (Traylor-Holzer, 2010). One such behavioural indicator that needs to be further addressed is pacing which is under behavioural estrus and stereotypical behaviours (Stanton et al., 2015). The combined data of Szokalski et al. (2012) reports that 16% of time spent by captive adult tigers is of stereotypical pacing. He further adds up that a more well-defined and uniform approach to data collection is strongly needed to accurately compare different enrichment techniques across animals and facilities as the behavioural categories used vary between studies.

### **3.0 METHODOLOGY**

#### **3.1 ETHICAL STATEMENT**

The research protocol in this study was approved by the Institutional Animal Care and Use Committee of Universiti Putra Malaysia with the reference number **UPM/IACUC/AUP-U040/2022** and PERHILITAN research permit (**JPHLTN.600-6/1/4 JLD 2 (77)**).

### **3.2 STUDY SITE AND ANIMALS**

The study was conducted at Malayan Tiger Conservation Centre (MTCC), Lanchang, Pahang, Malaysia for 14 days. One sexually immature male and one sexually mature female Malayan tiger with an estimated age of 2.5 years (M=Male, F=Female) were selected. These captive Malayan tigers were based on availability and permission obtained from PERHILITAN (research permit). The male is wild captured while the female was born in captivity and both were confirmed in good health and not pregnant during the study. The Malayan tigers are placed in the quarantine unit with 3 other female tigers. Both subjects are placed on the same side with 2 adjacent enclosures with a walkway in between allocated each for them. Tigers are changed among the 2 enclosures for husbandry management daily. All 4 enclosures are connected to one common play area paddock which consists of an artificial pond, tree barks, scrubs and enrichments. Both the tigers are let into the play area on alternative days for the whole day and cleaned thoroughly daily afterwards. Malayan tigers in captivity were temporarily managed under an intensive system by the management of MTCC. They were fed 6 days a week with different types of meat, live prey, and clean water and fasted on the 7<sup>th</sup> day. The facility is only entered by authorised personnel only for husbandry management, other than that the tigers are left undisturbed and not open to visitors.

### **3.3 ETHOGRAM BEHAVIOURAL OBSERVATION**

Observations were done on the animals through 2 cameras; a baby cam and Eken H6s 4K Action Camera, alongside CCTV using the focal sampling method (Crockett et al., 2010). Each slot represents an occurrence of reproductive behaviours at 1-minute intervals regardless of frequency are recorded. Cameras are set to record for

a fixed time of 0930 to 1630 for 14 days. The location of the cameras is changed daily based on the enclosure in which the animals are placed. Baby cam is placed at the entrance of the female tiger enclosure as she spends most of the time at that entrance and is not stressed by the visibility of the camera. As for the male, the Eken H6s 4K Action Camera is hidden between the vines and used to camouflage the enclosure's window opening so that it is not visible and does not further stress the male tiger as he easily gets stressed and agitated. Whenever the tigers are released into the play area, observations were recorded from the CCTV footage. All data and information within the sampling period regarding the animal behaviours described in the ethogram (Table 1) were recorded in the observation. The ethogram was constructed by incorporating some modifications. Only sexual behaviours listed below were recorded; normal behaviours like resting, feeding and hunting were not recorded.

<b>Reproductive behaviour</b>	<b>Code</b>	<b>Description of behaviour</b>
Pacing	P	Repetitive locomotion in a fixed pattern, such as back and forth along the same route.
Social roll	SR	Rolling over sides, then completely over on the floor, belly exposed and all paws in the air.
Prustening	PR	A greeting call that sounds like air expelled softly through the nostrils, creating a low-intensity, soft, pulsed sound, described as being similar to the snorting of a horse. Also known as chuffing.
Anogenital Groom	AG	Licking or grooming of anogenital area.

Urine spray	US	While standing with its tail raised vertically, the cat releases a jet of urine backward against a vertical surface or object. The tail may quiver as urine is discharged.
Clawing	C	Scratching of surfaces using claws of the forepaw.
Flehmen's response	F	An exaggerated open-mouth yawn, where it curls back its upper lip exposing its front teeth, inhales with the nostrils usually closed, and may have a protruding tongue used to discern the reproductive status.
Caterwaul	CW	Loud drawn-out whine. May be similar to yowl. (Vocalization)
Rubbing	R	Move the head or body against any surface with a certain amount of friction.

Table 1. Ethogram of male and female Malayan tiger reproductive behaviour

### 3.4 BEHAVIOUR STATISTICAL ANALYSIS

Microsoft Excel 2019 MSO (Version 2210 Build 16.0.15726.20188) and IBM SPSS Statistics software (Version 28.0) were used to analyse data. The data of each behaviour performed by male and female Malayan tigers throughout the 14-day study was calculated in the form of a percentage (Table 2). The percentage was calculated by dividing the number of behaviours recorded per minute daily by the total counted slots for each day. The total number of slots for each individual differs depending on the visibility of the animal by the observer throughout the sampling period. Therefore, all frequency data were calculated at the daily and individual levels.

Moreover, since most of the pacing behaviour was noticed during husbandry management of the facility, when there are humans present, the frequency of pacing during husbandry management (which is also known as anthropogenic disturbance for the tigers) is analysed. To determine the correlation between pacing behaviour with anthropogenic disturbance, Spearman's rho, a non-parametric correlation test with a significance level of  $\alpha = 0.05$  was performed.



## 4.0 RESULTS

### 4.1 REPRODUCTIVE BEHAVIOUR

A total of 4256 observation minutes for the male and 4632 observation minutes for the female are made. 521 reproductive behavioural records by female and 1451 records by male, inclusive of pacing are made.

Day	Individual	REPRODUCTIVE BEHAVIOUR								
		A	P	US	C	F	SR	PR	R	CW
1	F	0% 0/417	10.31% 43/417	0% 0/417	0.24% 1/417	0% 0/417	1.20% 5/417	2.16% 9/417	1.68% 7/417	2.40% 10/417
	M	0% 0/415	10.60% 44/415	0% 0/415	0% 0/415	0.24% 1/415	0% 0/415	0% 0/415	0.24% 1/415	0% 0/415
2	F	0.58% 2/342	5.26% 18/342	0% 0/342	0.88% 3/342	0% 0/342	1.17% 4/342	2.34% 8/342	3.51% 12/342	2.05% 7/342
	M	0% 0/218	57.55% 160/218	0% 0/218	0% 0/218	0% 0/218	0% 0/218	0% 0/218	0% 0/218	0% 0/218
3	F	0% 0/162	18.52% 30/162	0% 0/162	0.62% 1/162	1.23% 2/162	0% 0/162	1.23% 2/162	0.62% 1/162	2.47% 4/162
	M	0% 0/247	37.65% 93/247	0% 0/247	0% 0/247	1.21% 3/247	0% 0/247	0% 0/247	0% 0/247	0% 0/247
4	F	0% 0/114	0% 0/114	0% 0/114	0% 0/114	0% 0/114	1.75% 2/114	0% 0/114	0% 0/114	0% 0/114
	M	0% 0/229	75.11% 172/229	0.26% 0/229	0% 0/229	0.44% 1/229	0% 0/229	0% 0/229	0% 0/229	0% 0/229
5	F	1.22% 4/328	8.89% 29/328	0% 0/328	0% 0/328	0% 0/328	3.66% 12/328	0% 0/328	0.30% 1/328	1.22% 4/328
	M	0% 0/379	10.82% 41/379	0% 0/379	0.26% 1/379	0.26% 1/379	0% 0/379	0.53% 2/379	0% 0/379	0% 0/379
6	F	0% 0/238	0% 0/238	0% 0/238	0% 0/238	0% 0/238	0.84% 2/238	0% 0/238	0% 0/238	0.42% 1/238
	M	0% 0/103	42.72% 44/103	0% 0/103	0% 0/103	0% 0/103	0% 0/103	0% 0/103	0% 0/103	0% 0/103
7	F	0.27% 1/371	8.89% 33/371	0% 0/371	0.27% 1/371	0% 0/371	1.08% 4/371	0% 0/371	0.27% 1/371	2.16% 8/371
	M	0% 0/352	28.97% 102/352	0% 0/352	0.28% 1/352	0% 0/352	0% 0/352	0% 0/352	0.28% 1/352	0% 0/352
8	F	0.24% 1/414	0.97% 4/414	0% 0/414	0% 0/414	0.24% 1/414	1.69% 7/414	0% 0/414	0.72% 3/414	2.42% 10/414

	M	0% 0/217	2.76% 6/217	0.46% 1/217	0.46% 1/217	0.46% 1/217	0% 0/217	0% 0/217	0% 0/217	0% 0/217
9	F	0.24% 1/421	0% 0/421	0% 0/421	0.24% 1/421	0% 0/421	2.61% 11/421	0.24% 1/421	0.24% 1/421	0% 0/421
	M	0% 0/276	76.09% 210/276	0% 0/276	0% 0/276	0% 0/276	0% 0/276	0% 0/276	0% 0/276	0% 0/276
10	F	0.24% 1/421	6.89% 29/421	0% 0/421	0% 0/421	0% 0/421	0.71% 3/421	0% 0/421	0% 0/421	0.48% 2/421
	M	0% 0/413	24.21% 100/413	0% 0/413	0% 0/413	0.24% 1/413	0% 0/413	0% 0/413	0% 0/413	0% 0/413
11	F	0.48% 2/418	0% 0/418	0% 0/418	0% 0/418	0% 0/418	3.35% 14/418	0% 0/418	0.48% 2/418	0% 0/418
	M	0% 0/313	56.55% 177/313	0% 0/313	0% 0/313	0% 0/313	0% 0/313	0% 0/313	0% 0/313	0.32% 1/313
12	F	0% 0/277	3.97% 11/277	0% 0/277	0.36% 1/277	0% 0/277	0.72% 2/277	0.72% 2/277	1.44% 4/277	3.61% 10/277
	M	0% 0/421	23.75% 100/421	0% 0/421	0% 0/421	0.24% 1/421	0% 0/421	0% 0/421	0% 0/421	0.24% 1/421
13	F	0.35% 1/288	0% 0/288	0.69% 2/288	0.69% 2/288	0.35% 1/288	0.69% 2/288	0% 0/288	1.74% 5/288	0% 0/288
	M	0% 0/396	30.8% 122/396	0% 0/396	0% 0/396	0% 0/396	0% 0/396	0% 0/396	0% 0/396	0.25% 1/396
14	F	0.48% 2/421	5.94% 25/421	0% 0/421	0% 0/421	0% 0/421	1.19% 5/421	0% 0/421	0.95% 4/421	2.14% 9/421
	M	0.26% 1/277	21.66% 60/277	0% 0/277	0% 0/277	0.36% 1/277	0% 0/277	0% 0/277	0% 0/277	0% 0/277

Table 2. The frequency of reproductive behaviour was recorded from both male and female Malayan tigers at MTCC.

From Table 2, there were major differences between male and female sexual activities. Female showed a higher frequency of reproductive behaviours throughout data collection ( $9.93 \pm 6.92$ ). Urine spraying was only noticed only once on D13. The frequency of caterwauling was 65 times. Flehmen's response was only noticed on D3 (1.23%), D8 (0.24%) and D13 (0.35%). Out of 14 observation days, there is an almost steady increase in the frequency of all reproductive behaviour on D1, D2, and D3 except for pacing and social role. There is also a drop in pacing on alternate days like

D4, D6, D9, D11, and D13. These were the days the female was released into the play area where she spends most of her time resting in the pond, hunting and feeding. Nevertheless, only observations of sexual behaviours were recorded from the CCTV footage.

According to Figure 2, SR observations of the female are mostly seen at 10 am, 2 pm and 3 pm. The highest frequency of sexual behaviours in female was at 12 pm at 19% (88 / 456 total counted slots of sexual behaviours). Sexual behaviours seen at 12 pm are pacing (40 times), caterwaul (14 times), rubbing (11 times), social roll (9 times), prustening (4 times), clawing (4 times) and Flehmen's response (2 times) in descending order of frequency.

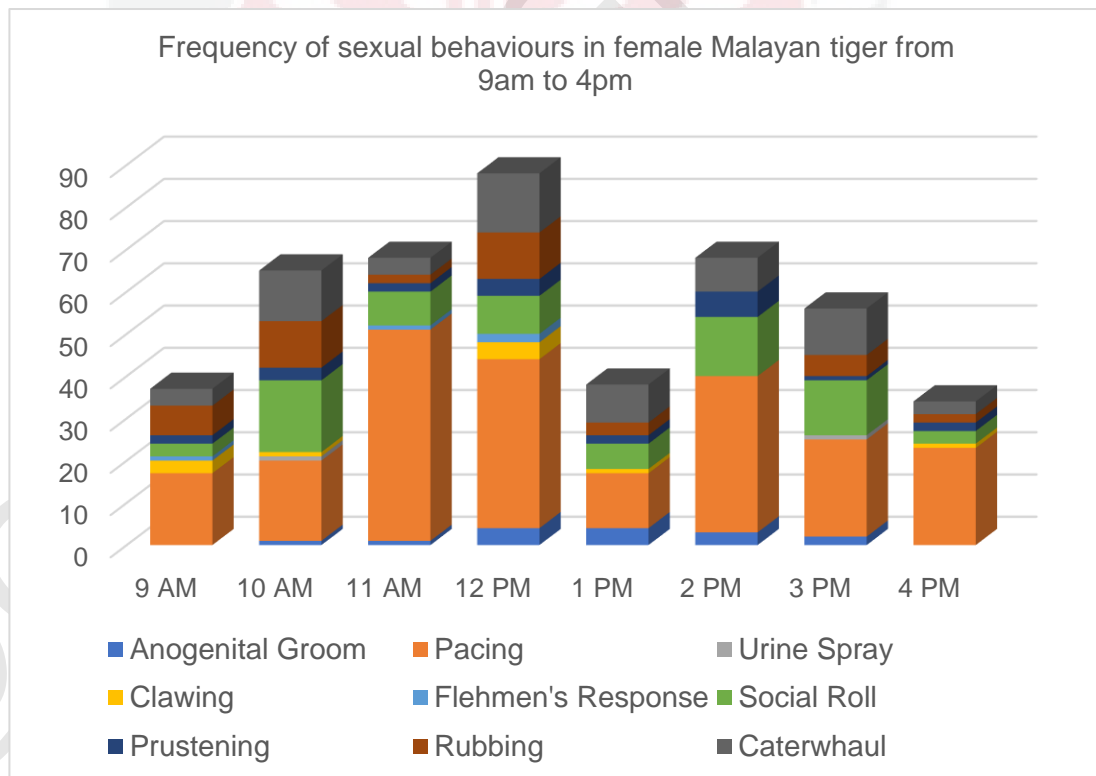


Figure 2. Frequency of sexual behaviours in female Malayan tiger at MTCC throughout the day.

From Table 2, it can also be deduced that the sexually immature male has shown reproductive behaviour not more than the daily frequency of 1.21% when pacing is excluded. No caterwaul and social rolling were seen. Urine spray was seen once on D8 while clawing was on D5, D7, and D8. Pacing and rubbing were commonly noticed. Nevertheless, when both male and female sexual behaviour trends are juxtaposed in a stacked line graph, a specific correlation pattern is seen as shown in Figure 3. Figure 3 shows a very weak but synchronous increase in reproductive behaviours of both male and female on D3, D5, D7, D10, D12 and D14. D14 is also the day that the male exhibited anogenital groom for the first time throughout the 14 days of observation.

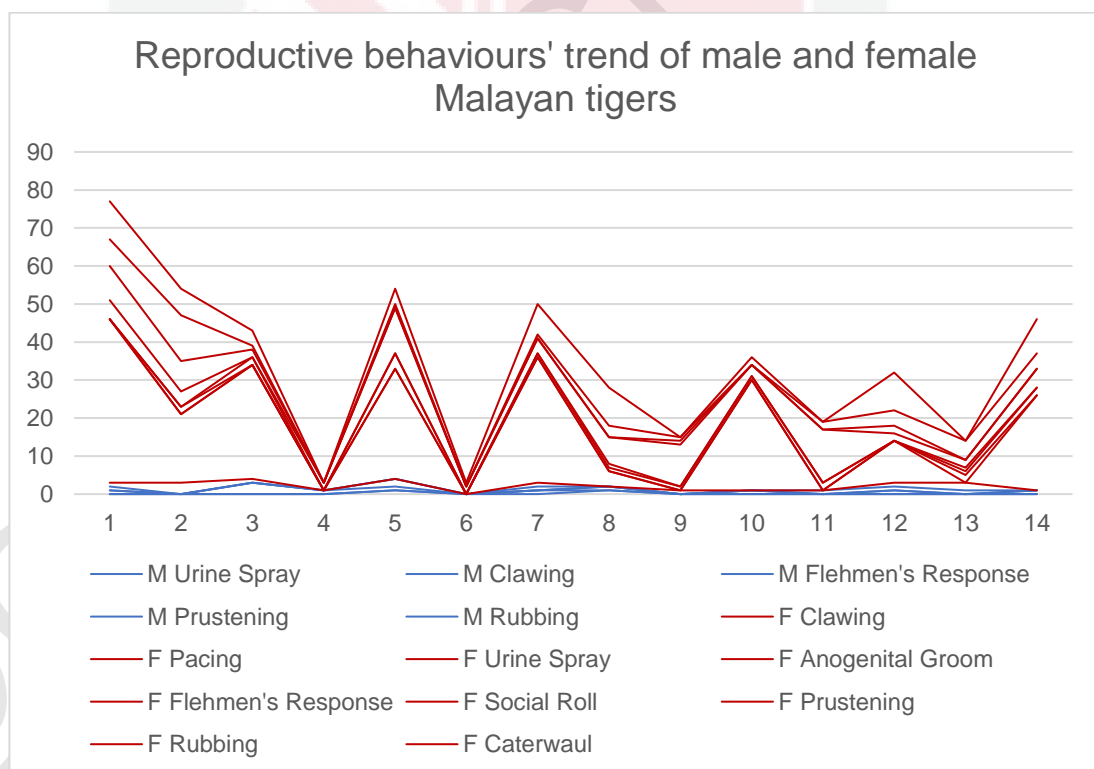


Figure 3. Reproductive behaviours' trend of male and female Malayan tigers at MTCC.

#### 4.2 PACING AND ANTHROPOGENIC DISTURBANCE

Out of 521 reproductive behavioural records by female and 1451 records by male, 222 and 1431 observations are of pacing. Table 3 shows the frequency of pacing of both male and female during husbandry management and other times. 41.72% of pacing seen in the male happens during husbandry management while 30.2% is seen in the female although the total pacing seen in the male is more than the female.

Individual Days / Husbandry Management	Male		Female	
	Yes	No	Yes	No
1	100% (44/44)	0% (0/44)	20.93% (9/43)	79.07% (34/43)
2	61.88% (99/160)	38.13% (61/160)	66.66% (12/18)	33.33% (6/18)
3	79.57% (74/93)	20.43% (19/93)	6.67% (2/30)	93.33% (28/30)
4	17.44% (30/172)	82.56% (142/172)	0	0
5	87.80% (36/41)	12.20% (5/41)	24.14% (7/29)	75.86% (22/29)
6	2.27% (1/44)	97.73% (43/44)	0	0
7	16.67% (17/102)	83.33% (85/102)	42.42% (14/33)	57.58% (19/33)
8	33.33% (2/6)	66.67% (4/6)	0% (0/4)	100% (4/4)
9	33.81% (71/210)	66.19% (139/210)	0	0
10	70% (70/100)	30% (30/100)	48.28% (14/29)	51.72% (15/29)
11	5.08% (9/177)	93.79% (168/177)	0	0
12	81% (81/100)	19% (19/100)	9.09% (1/11)	90.9% (10/11)
13	41.80% (51/122)	58.20% (71/122)	0	0
14	20% (12/60)	80% (48/60)	32% (8/25)	68% (17/25)
Total	41.72% (597/1431)	58.28% (834/1431)	30.2% (67/222)	69.82% (155/222)

Table 3. Frequency of pacing of both male and female tigers at MTCC in the presence and absence of husbandry management

Based on Figures 4 and 5, the pacing is most noticed at 9 to 10 am with anthropogenic disturbance for both male and female which is also the most consistent time of husbandry management. Husbandry sometimes finishes at 10 am or gets extended up to 11 am or even noon.

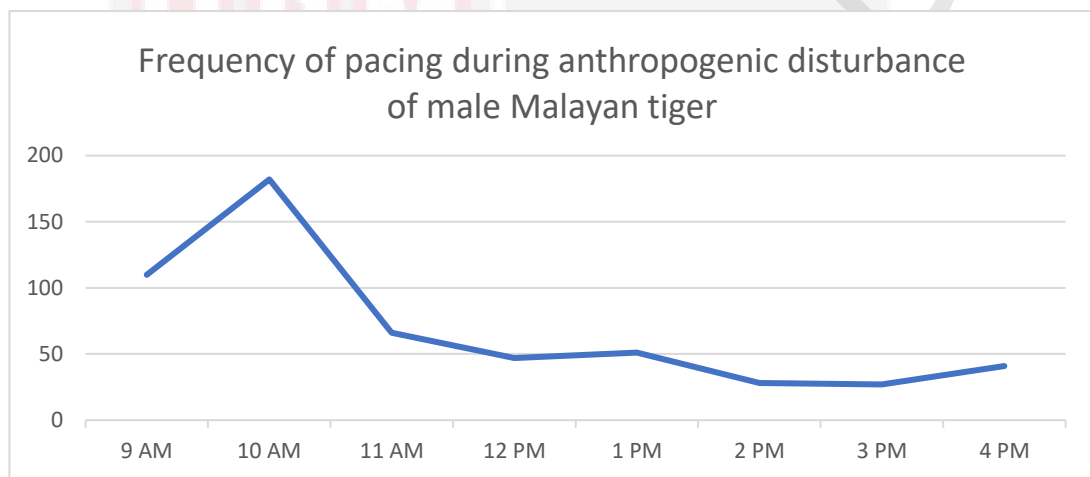


Figure 4. Frequency of pacing during anthropogenic disturbance of male Malaysian tiger at MTCC.

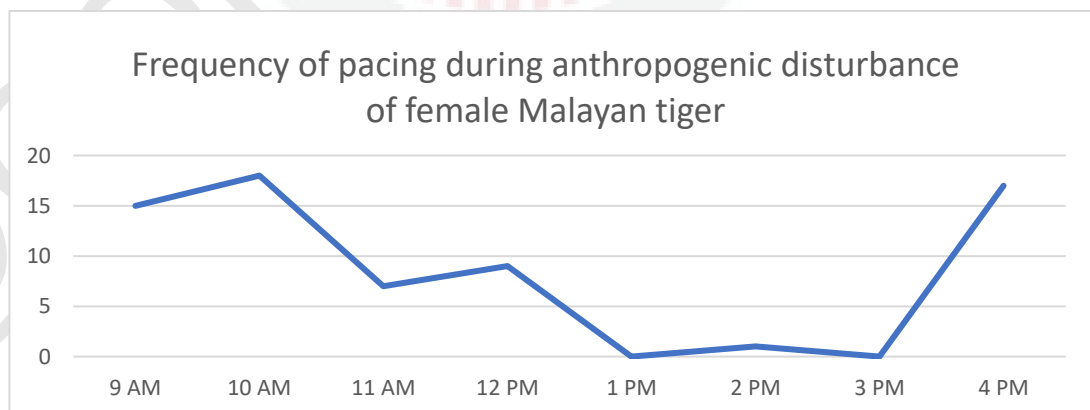


Figure 5. Frequency of pacing during anthropogenic disturbance of female Malaysian tiger at MTCC.

Table 4 depicts the correlation coefficient between total pacing per day and anthropogenic disturbance during pacing. Pacing was significantly correlated to anthropogenic disturbance. However, the male had a poor correlation with a correlation coefficient of 0.247 ( $p < 0.001$ ) while the female had an even poorer correlation with a correlation coefficient of 0.039 ( $p < 0.008$ ).

<b>Spearman's correlation</b>		<b>Correlation coefficient</b>	<b>Significant figure (2-tailed)</b>
Male	Total pacing per day Total anthropogenic disturbance during pacing	0.247	<0.001
Female	Total pacing per day Total anthropogenic disturbance during pacing	0.039	0.008

Table 4. Correlation between pacing and anthropogenic disturbance

## 5.0 DISCUSSION

### 5.1 REPRODUCTIVE BEHAVIOUR

Tigers exhibited more mobility, maintenance, and solitary play in the daytime (Baker et al. 2006), which supports the findings from our study. Similarly, both male and female tigers spend less time during the day in exhibiting sexual behaviours. Nevertheless, the tigress showed more sexual behaviour than the male since it showed increased stimulation in the frequency of calling, rolling and rubbing on the ground (Baker et al., 2006, M and F Sunquist, 2002).

Studies based on those in captivity state that the tigresses' scent mark was more frequent right before the peak of estradiol which function is to ensure that a male is present at the appropriate time. In contradiction to that, urine spray was only observed once not during estrus. This could be suggestive of tigers who may use a

wider range of non-contact communication techniques such as chuffing (Pastorino et al., 2021). The importance of the different behaviour of lacking in urine spray should be investigated further in the Malayan tiger. As for the specific incidence of Flehmen's response in the tigress on D3, D8 and D13, it is an investigative behaviour evoked by urine. On Day 3, male urine was sprayed on the tree of the enclosure as weekly enrichment. As for Day 8 and Day 13, this behaviour was seen in the same area where the male was noticed to be present, urinated and defecated. This behaviour allows less volatile material such as hormones to be detected by sensory neurons in an accessory olfactory organ, the vomeronasal organ (Senger, 2012).

Moreover, Brown (2011) also stated that female receptivity lasts for 3 to 10 days but behavioural estrus is highly notifiable to the male's advances for 2 to 3 days of each estrous cycle. This is the reason why the male could find the tigress during her peak of receptivity according to Baker et al., 2006. This suggests that D1 to D3 could be the peak estrus of the female subject since almost all of her sexual behaviours were high with no major fluctuations. As shown in Figure 6, our results coincide with the schematic illustration of the supposed estrous cycle of a tiger.

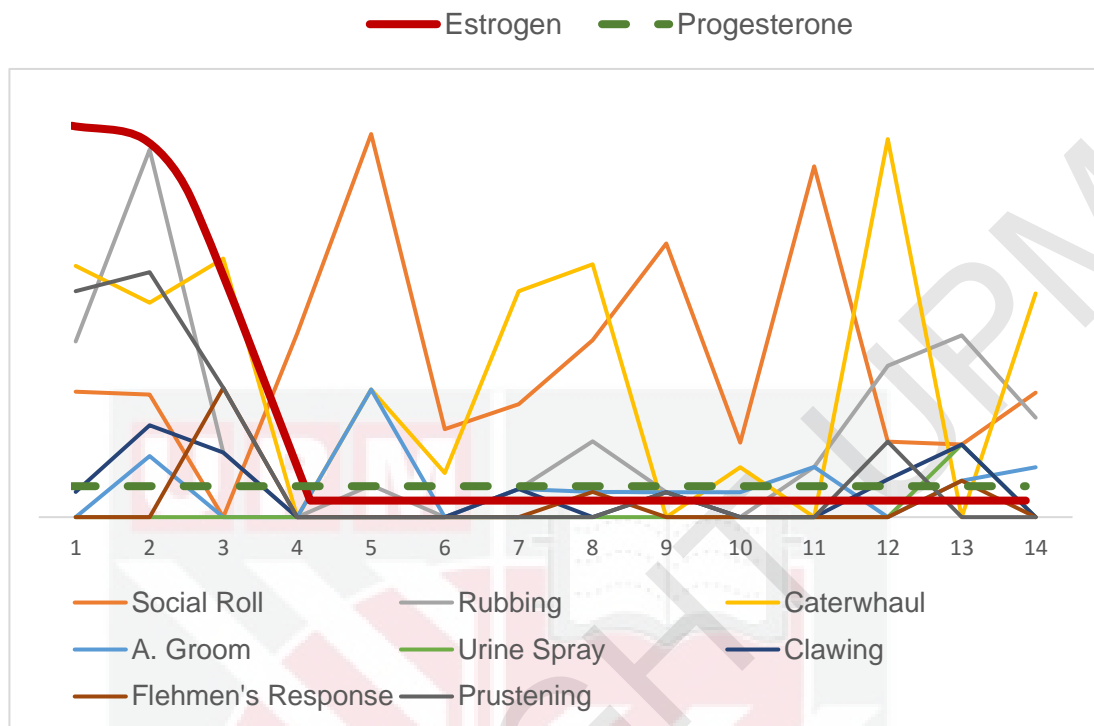


Figure 6: Comparison of female sexual behaviour with induced ovulation patterns of estradiol (red line) and progesterone (dashed green line).

Other than that, Bashaw et al. (2007) & DeRouck et al. (2005) suggest that tigers display more pacing when housed adjacent to other tigers which further explains the drop in pacing on alternate days when released into the play area when she is not close to the female. Furthermore, the increased frequency of sexual behaviours in the afternoon could be explained by the phenomenon of tigress not being affected by high daytime temperatures and not being exposed openly under the sun, explained in previous works of Sunquist (1981; 2010). Tiger's seasonal activity patterns seem influenced via means of numerous environmental factors, including the activity schedules of prey and human interaction, probably temperature, and there may well be fine-grained intra-specific variations among sexes relying on reproductive condition. The possible effect of husbandry management on increase

in the female's reproductive behaviour to be seen at 12 pm would be further investigated in the next section below.

As for male reproductive behaviours, it is remarkably lower than the female. One of the possible reasons for the incidence of these behaviours once or twice is the sexual maturity of the tiger. According to Mazak (1981), sexual maturity is reached at 3 to 4 years old in females and 4 to 5 years old in males. Since both tigers are rough of the same age (2 ½ years old), the male tiger needs more time to sexually mature. The libido of males, assumed from vocalization and flehmen's response is stimulated by the female on estrous, which is followed by the behavioural estrus (Putranto et al., 2007). This explains the very weak yet synchronous increase of male reproductive behaviour towards female activities. Nevertheless, no significant steady increase in the male's sexual behaviour, especially pacing and flehmen's response was seen on the days of suspected behavioural estrus of the female (D1 – D3). Thus, the phenomenon that is observed in this study explains the transition stage from the pre-puberty to puberty phase in a male tiger.

## **5.2 PACING AND ANTHROPOGENIC DISTURBANCE**

Many studies have employed pacing as a suboptimal indicator of stress and welfare for many captive animals such as captive lynxes, tigers, African elephants and jaguars (Szokalski et al., 2012; Rasmussen et al., 2008; Tyagi et al., 2019). Repetitive behaviour patterns with no discernible goal or function like pacing, bar biting, self-biting, repetitive vomiting and more are caused by multifactorial aspects such as anxiety, annoyance, anger, fear, frustration, lack of space in the cages, changes in zoo environment or even sexual motivation (Haque, 2011). Severe zoochosis (stereotyped behaviours) can cause health issues like severe dental wear with

complicated incisor fractures due to bar/fence biting (Konjević et al., 2015). Szokalski et al. (2012) suggest that increased pacing and frequent head movement can indicate stress and a greater escape motive which could apply to the male subject as it was captured from the wild.

The occurrence of increased frequency of pacing during an anthropogenic disturbance, especially on husbandry management periods when tigers in captivity at this facility are in the closest proximity to the keepers could be a sign of physiological stressors. The possibility of pacing due to hunger or response to visual or olfactory stimulation of the feed is eliminated since the feed is placed within the enclosure before the start of behavioural observations. Whatever movement was done to hunt the feed was not recorded as pacing. Tyagi et al. (2019) and Fanson et al. (2019) indicate that human interaction can elevate physiological stress in tigers which is significantly higher in captive wild felids, which may have an impact on population reproductive potential. Due to this, auto-grooming also decreased and was only seen on D14, possibly due to increased vigilance and pacing (Wielebnowski et al., 2002). Other than that, the highest frequency of sexual behaviour was seen at 12 pm as husbandry management sometimes gets extended up to 11 am or even noon. Thus, 12 pm was the most consistent time at which no anthropogenic disturbance was seen which could be another inference for the increased reproductive activity of the tigress.

## **6.0 CONCLUSION**

The null hypothesis is rejected. There is a difference in reproductive behaviour between males and females. In short, sexual behaviours such as social roll, prustening, anogenital groom, clawing, flehmen's response, caterwaul and rubbing are good reproductive status indicators of Malayan tigers. Estrus could be suspected through sexual behavioural observations. A sexually immature male tiger subtly responds to the sexual behaviours of the female. Behaviours like flehmen's response, vocalization, and anogenital grooming could be used as pointers for future studies in determining the sexual maturity of the tigers. Pacing is likely an exception as a reproductive status criterion, especially for wild captured tigers as it could be stereotypical behaviour that needs to be further investigated.

## **7.0 RECOMMENDATIONS**

For future studies, it is highly recommended to use a sample size with various reproductive statuses of the same sex. This is to gather more information and to discern the difference between pre-puberty, sexual maturity, gestation, lactation and anestrus phase.

Furthermore, because there is no standardised ethogram for documenting tiger behaviour, studies differ in the stereotypical, passive and sexual behaviour categories, making comparisons difficult. A more defined and consistent approach to data collection inclusive of stereotypical behaviour and reproductive behaviours is required to accurately compare data. It is also advisable to also record the possible causes of behaviours accordingly to gain better inferences about tiger psychology. For example, pacing could be seen due to hunger-triggered smell or sight of feed, the presence of human or prey birds within the compound and even other stressors.

Besides, a longer duration of study is very crucial to record multiple behavioural estruses to get a more concise and average result. Internal and environmental factors such as photoperiodicity, weather, management, etc are confounding factors that need to be addressed, and prolonged observations under different conditions to obtain a more unbiased sample size of statistical analysis. Moreover, the introduction of a camera within the enclosure could be considered foreign thus, it may stress the tigers in the beginning. Since only one estrus is seen, results are skewed to a single occurrence of the sample. If more estruses are observed, a more consistent and accurate statistical result would be gained. Therefore, a longer duration may remove the uncertainty of behavioural estrus and its indicators.

Other than that, a joint study of behavioural and endocrinological studies should be carried out. Endocrinological studies using non-invasive faecal hormonal assay using hormones like androstenedione, progesterone, estradiol and testosterone are highly recommended. This can help get a more physiologically and psychologically accurate estimation of the estrous cycle and sexual maturity when comparing and analysing the mean of both data. This can also infer that pacing likely to be caused by stress or response to pheromones through hormonal assay.

Furthermore, instead of one camera for each tiger, it is recommended to use multiple cameras at different angles, this will minimize the blind spots. Out-of-sight observations, the total calculated slots daily are not consistent; thus, the duration of the experiment is no longer controlled. Besides that, the observer may interpret certain behaviours differently as sexual or stereotypical behaviours based on statistical analysis and errors of apprehension This is because the sum of calculated observations per day is inconsistent because there are "out of sight" observations

despite having a fixed duration. This enables a more unbiased data collection and increases the accuracy of results.



## 8.0 REFERENCES

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## 9.0 APPENDICES

### Appendix A: Correlation between Pacing and Anthropogenic Disturbance.

#### Nonparametric Correlations of Male Malaysian tiger.

##### Correlations

				Pacing	Anthropogenic Disturbance
Spearman's rho	Pacing	Correlation Coefficient		1.000	.247**
		Sig. (2-tailed)		.	<.001
		N		4256	4256
	Anthropogenic Disturbance	Correlation Coefficient		.247**	1.000
		Sig. (2-tailed)		<.001	.
		N		4256	4256

\*\* Correlation is significant at the 0.01 level (2-tailed).

#### Nonparametric Correlations of Female Malaysian tiger.

##### Correlations

				Pacing	Anthropogenic Disturbance
Spearman's rho	Pacing	Correlation Coefficient		1.000	.039**
		Sig. (2-tailed)		.	.008
		N		4632	4632
	Anthropogenic Disturbance	Correlation Coefficient		.039**	1.000
		Sig. (2-tailed)		.008	.
		N		4632	4632

\*\* Correlation is significant at the 0.01 level (2-tailed).