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Photographic Identification of Individual Red Panda (*Ailurus fulgens* Cuvier, 1825)

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Abstract This study was carried out to identify individual red panda (*Ailurus fulgens*) through photographs and develop a protocol for their identification from pelage patterns. Manual observation method for photo-identification was applied for matching natural markings and statistical tools like Kruskal-Wallis tests and Sensitivity and Specificity tests were used during the analysis. Out of the three different sections considered in the study, contribution of head section was recorded to be the most significant (77.33%) followed by tail (53.33%) and mid section (50.66%) for discriminating individual red panda. Similarly, head section's contribution was remarkable (60%) in distinguishing juvenile and adult red panda. This study also helped reveal out some discriminating features in tail, ear, pelage-coloration, tear drop and patches of juvenile and adult red panda. Four major types of facial patterns (Bald, Murky, Faint and Shiny) and 12 morphological features including five primary and seven secondary features were recorded for identifying individual red panda.

Keywords: *individual identification, invasive marking, natural marking, photo-identification, red panda*

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1. Introduction

Photo-identification is one of the most effective, non-invasive and popular methods of recording natural markings to distinguish individual animal which allows the study of animal movement patterns, site fidelity, population size and other population parameters with the only field requirement being a suitable camera [1]. Use of this methodology in capture-mark-recapture studies has expanded rapidly since the 1960's as biologists look for less-invasive, permanent and cheaper marking techniques for large numbers of individual animals [2]. Photographic identification has been so far adopted for the wild animals in a number of studies like *Panthera tigris*, *P. pardus* [3], *P. onca* [4], *Leopardus pardalis* [5], *Chrysocyon brachyurus* [6], *Puma concolar* [7], *Cuon alpins* and *Panthera tigris* [8], *Uncia uncia* [9].

Photographic approaches can be divided into two broad categories- active and passive, depending on the level of interaction required with the animals. Aerial photography and the use of remote or infrared camera traps are considered passive since they do not involve direct human interaction with the animal being photographed [10]. Alternatively, moving closer to an animal or capturing it in order to obtain a photograph is considered an active approach since it involves direct human interference with the animal [11]. Whether active or passive, and particularly since the development of the digital camera, photography remains one of the fastest and cheapest means of "marking" large numbers of individuals in a population [12]. Combination of visual differences in the physical structure, form of individual animals and patterns of pigmentation provide the basis for identification of individual animals [13,14].

Gathering information on population and distribution for threatened species like red panda is both time and resource consuming. Furthermore, its rarity, small body size and distribution in remote-rugged habitat have limited its detection probability during field surveys. The similar morphology and coloration of their body again makes it difficult to distinguish different individuals even if they are spotted at different occasions. Therefore we have developed a protocol for identifying individual red panda from their pelage patterns and differentiation between juvenile and adult red pandas. We hope this work will help solve the problem of identifying individual red panda captured through the photographs and camera-trappings.

2. Materials and Methods

As many as 110 photographs and 28 videos of red panda were collected from different sources including researchers, organizations (especially zoos) and online

forums. Each photograph was categorized into head section, mid section and tail section to assess the utility of each section in aiding individual identification. Later on we developed a null hypothesis (H0) - there is no significant difference in usability categorization of red panda body sections (i.e. head, mid and tail) across the observers.

2.1. Protocol for Red Panda Identification

A total of 30 photographs of 15 different red pandas were distributed among the five primary observers to assess the reliability using matrix, who had no fore-knowledge of individual red panda identity. Pre-test was conducted prior this observation consisting of photos of known red pandas, to assess observer skill (observer who give <90% of answers within the range of possible answers in pre-test deemed unequipped). Red panda identification uncertainty was confounded by lighting, angle, distance from the camera or flash, and wetness of fur. Precautions were taken to overcome the uncertainties by designating identifying features for each individual and terminologies were developed. It was followed by blind identification test following the guidelines provided by Kelly et al. [15], at the same time, percentage of pair wise and five-way exact matches and complete disagreements among observers were conducted. The resultant data sets were analyzed to assess the percentage of exact matches among all five observers for each body part.i.e. head, mid and tail, based on their usability. Kruskal-Wallis test 'H' [16] was applied for testing significance of difference in usability categorization of each part across observers.

2.2. Individual Identification of Juvenile and Adult Red Panda

Table 1. Table for Calculating Sensitivity and Specificity

(+VE)	TP	FP
(-VE)	FN	TN

Altogether 30 photographs of different individuals including 15 adults and 15 juveniles were used. A matrix was developed to compare the photographs for the observers. They were repeatedly asked the same question - Is this the juvenile or adult red panda? At least three key features different from those of previously identified red pandas were used in identifying an individual. Finally, "blind" technique was developed and all the photographs were presented to primary observers (n=5) to repeat above step. Orientation was given to the primary observers regarding known pelage morphology of known juvenile and adult red panda, (observers who gave answer <90% of answers within the range of possible answers in pre-test deemed unequipped). Selectivity (also called the true positive rate, or recall rate in some fields) measures the proportion of actual positives which are correctly identified as such (e.g. when primary observer identifies the same panda as secondary observer did.i.e. "I") and specificity (sometimes called the true negative rate) measures the proportion of negatives which are correctly identified as such (e.g. when primary observer could not identify a panda that secondary observer could not identify.i.e. "I") were measured across observers for accounting inter observer variability.

$$Sensitivity = \frac{TP}{TP + FN} X100 \quad (1)$$

$$Specificity = \frac{TN}{TN + FP} X100 \quad (2)$$

Where, TP= True positive, FP= False positive, FN= False negative, TN= True negative

3. Results

3.1. Protocol for Red Panda identification

The blind observation was conducted using a total of 30 photographs as a sample. The average pair wise agreement on identification of red panda was high at 80% (range 67–87%). The five-way agreement across the observers was lower at 67%. None of the photographs were regarded as average five-way disagreement (all five observer assigned different identities to a photograph).

This test concluded the significant difference in categorized body sections (i.e. head, mid and tail sections) and provided the significant evidence of certain categorized body sections heavily contributing in individual identification of red panda (Kruskal-Wallis H=8.685, df=2, p>0.05). The sum of ranks for head section was recorded to be the highest (64) followed by tail section (29.5) and mid section (26.5) across the observers which are shown in Table 2. It indicated towards the significant contribution of head section in the identification of individual red panda. Head and tail sections were used more successfully in classifying the given photographs with the contribution of 77.33% and 53.33% respectively. Although the five observers differed significantly in classifying photographs using mid section, they were more consistent in identification when using the other sections of the photographs. The number of red pandas identified by observers ranged from 10 to 13 out of the provided photographs of 15 different red pandas.

Table 2. Ranks Given by the Observers for Categorized Body Sections

Observer	Categorized Body Sections					
	Head	Rank	Body	Rank	Tail	Rank
1	11	12	8	5.5	6	2.5
2	12	13.5	10	10	7	4
3	13	15	6	2.5	9	7.5
4	10	10	5	1	10	10
5	12	13.5	9	7.5	8	5.5
Sum of Ranks		64		26.5		29.5

This study revealed that the number of tail rings and facial markings have remarkable contribution for identifying individual red panda, as the number of alternating rings varies considerably from 12 to 18. At least 4 different types of facial patterns were identified which is shown in Table 3. Those patterns often have subtle variations.

Table 3. Common Facial Patterns of Red panda

Name	Features	Adopted artistic conception
Faint	Thin cheek mark with single layered crown.	
Shiny	Cheek mark is broader and shiny.	
Murky	Cheek mark is triangular and other marks clearly invisible.	
Bald	White pelage coloration starting above the forehead, goes up to the muzzle, extends beyond the nose-bridge to the side of the face and tear-drops and cheek marks indistinct.	

As many as 12 morphological features were identified which were further categorized into two classes including primary and secondary features which is shown in Table 4. Primary features are those which are supposed to remain consistent in the body throughout their life span, and secondary features are those which may change during a period of time.

Table 4. Morphological Features for Red panda Identification

S.N.	Features	Insights
a.	**Primary features.**	
1.	Facial Patterns	i) Faint ii) Shiny, iii) Murky and iv) Bald
2.	Nose-bridge	i) Downward pointed ii) Upward pointed iii) Irregular and iv) Not visible
3.	Muzzle tip	i) Square (□) ii) Triangle (△) iii) Trapezoid (⏢) and iv) Others
4.	Tear-drop	i) Narrow ii) Broad iii) Light iv) Dark
5.	Tail rings	Fixed number of light and dark rings (n=12, 13, ….18)
b.	**Secondary Features**	
1.	Ear rim	i) Thin and ii) Thick
2.	Ear-core	i) Visible ii) Partly visible iii) Invisible
3.	Shape of Crown	i) Single layered ii) Double layered and iii) Not distinct
4.	Shape of Cheek Mark	i) Thin ii) Broad iii) Triangular and iv) Not distinct
5.	Fluffy white patches	May present on i) Flanks ii) Shoulder and iii) Absent
6.	White, reddish or gingery patch	i) Forelimbs ii) Hind limbs and iii) Claws
7.	Coloration of Rump	i) Dark ii) Light and iii) Same that of Flanks

3.2. Identification of Juvenile and Adult Red Panda

Of the 30 photographs of red panda, primary observer discriminated 87% (n=26) red pandas including 50% (n=13) of each. Head section's contribution was remarkable in 60% (n=16) of the provided photographs. Five primary observers identified the same red panda with sensitivity of 84.60% and 87.68% for juvenile and adult respectively. At the same time, they failed in identifying same red panda with the specificity of 87.68% for each group which is shown in Table 5. Those observers discriminated 22 red pandas including 11 juveniles and 11 adults out of 30 individuals in the provided photographs.

Table 5. Sensitivity and Specificity for Juvenile and Adult Red panda

Observer	Sensitivity (%)		Specificity (%)	
	Juvenile	Adult	Juvenile	Adult
1	84.60	92.30	84.60	84.60
2	92.30	92.30	84.60	84.60
3	76.90	84.60	92.30	92.30
4	84.60	84.60	92.30	92.30
5	84.60	84.60	84.60	84.60
Mean	84.60	87.68	87.68	87.68

We identified a number of morphological discriminating features including ear; tear drop, patches (spots); pelage coloration and tail between juvenile and adult red panda (Table 6). The adopted illustration for distinguishing juvenile and adult red panda based on the result drawn from independent reviewers is shown in Figure 1.

Figure 1. Morphological differentiation between juvenile and adult red panda (Adopted artistic conception)

Table 6. Discriminating Features of Juvenile and Adult Red panda

Discriminating Features	Juvenile	Adult
Ear	Thick ear rim, shorter fluff and most of the time ear core invisible.	Medium rim, longer fluff and most of the time ear core visible.
Tear drop	Not finely defined, narrow and murky.	Finely defined, thick and dark.
Patches (spots)	Presence of murky white patches on the flanks and limbs.	Murky white patches may not be present.
Pelage coloration	Blurry contour line, lighter coloration of the rump.	Sharp contour line, darker coloration of the rump.
Tail	Fluffy with indistinct narrow rings, short with blunt tip.	Cylindrical with well distinct broad rings, longer with pointed tip.

4. Discussion

This is the first attempt to identify individual red panda through their photographs. Individual identification can be used to estimate population size, develop life histories, distribution and document some aspects of behavior, all of

which leads to more effective management, interventions and conservation. Although individual identification of red panda was not possible from all available photographs, the 100% agreement of all primary observers 20 (67%) out of 30 photographs, show that this method could be effective. This study presents photographic method as a promising new approach to reliably identify individual red panda. Although red pandas have persistent markings, there was considerable subjectivity in assigning individual identities to photo-captures. In fact, the blind identification of individuals reveals the extent of discrepancies among the investigators in identifying individual red panda. Reference [17] also recorded the similar findings in hyena *Hyaena hyaena*.

Comparatively speaking, individual identification of red panda is more difficult than that of Andean bear (*Tremarctos ornatus*), cheetah (*Acinonyx jubatus*), common leopard (*Panthera pardus*) and jaguar (*Panthera onca*) due to their shiny fur, diffuse coloration-patterning, and small body size. Although the short hair and distinct markings on the face exhibited the highest degree of variability and this is most useful part of the body in individual identification of red panda.

Involvement of primary observer is important to correct the observer biasness. Observation process should be calibrated to account for varying levels of observer experience with identification of individual animals. Reference [18] used a rigorous method on Andean bears *Tremarctos ornatus*, for comparing observer comments to account for observer biasness by assigning a point value: "Definitely the same" = 2, "Probably the same" = 1, "Unable to determine" = 0, "Probably different" = -1 or "Definitely different" = -2. When the answers of all the observers were summed up, higher positive numbers indicated greater confidence that the bears were the same, lower negative numbers indicated greater confidence that the bears were different, and numbers close to zero indicated an inability to determine whether the bears were the same or different. This method could be combined with the above pretest on captive red panda identification when there are many primary observers.

High sensitivity (86.14%) and specificity (87.68%) indicates the photographic method is suitable for identification of juvenile and adult red panda. The identification of juvenile and adult red panda raises an interesting question whether individual juvenile red panda can be used in identification of adult red panda: Do the facial pattern changes over a time? Historically, biologist thought patterning changed as the animal aged and was linked to gender, heredity and geographic origin [19]. However, he disputed these earlier claims based on his observations of captive bear populations, stating that patterning remained consistent from birth, except for slight fading with age. He also concluded that variations are not connected to gender or heredity. He proposed patterns could be linked to geographic origin but without more information he could not be conclusive about this claim. Our own informal inquiry on this subject regarding red panda has been inconclusive.

5. Conclusions

The manual method of handling images has proven an uncomplicated, yet effective approach for photographically identifying individual red panda in diverse environmental conditions. Optimization of photographic quality is particularly important for manual methods where overall error rate and per comparison time tend to increase with the inclusion of poor quality photographs. Similarly, accounting for differences in observer(s) experience level as well as distinctiveness of individuals is important as those factors also impact errors and can bias the result. The study concluded that primary and secondary features should be examined to identify an individual red panda. In addition to those morphological features there could be other markings including broken tail, incomplete external ear pattern and scars which might significantly contribute in individual identification of red panda. Likewise, the morphological features including ear, tear drop, patches (spots), pelage coloration and tail recorded as the discriminating markings between juvenile and adult red panda.

It is hoped that this basic classification framework provides a useful contextual background for researchers considering photographic identification. Keeping in mind the potential mark types, methods, and key issues during all phases of the study should reduce the confusion that has historically been a problem in a very diverse field. Present study could not incorporate sexual diamorphism aspect which has been recommended for further exploration.

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Statement of Competing Interests

The authors have no competing interests.

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