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Wildlife Emotion Analytics Framework for Evaluating Animal Stress Responses Near Human Settlements

Dr. Ratna Sonekar[1*], Dr. Abhinesh Kumar Tandan[2], Soumi De[3]

[1]Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.*
Email: ku.ratnasonekar@kalingauniversity.ac.in, ORCID: https://orcid.org/0009-0005-6899-7761
[2]Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.
Email: ku.abhineshkumartandan@kalingauniversity.ac.in, ORCID: https://orcid.org/0009-0004-4549-8997
[3]Assistant Professor, New Delhi Institute of Management, New Delhi, India.
Email: soumi.de@ndimdelhi.org, ORCID: https://orcid.org/0009-0007-3615-2291

Key Words

Animal stress physiology, Wildlife behaviour, Human disturbance, Glucocorticoids, Flight initiation distance, Conservation physiology.

Abstract

Human expansion into wildlife areas results in a close interaction of humans and free-roaming wildlife in environments exposed to noise, light, traffic, and the presence of humans. There is an urgent need to reliably evaluate the stress response in order to provide guidance for conservation action and ensure animal welfare. The aim of this paper is to present the Wildlife Emotion Framework a conceptual and methodological structure based exclusively on well-established concepts of animal science to estimate stress in wild animals residing near human settlements. It consists of three domains that are evaluated together to measure the level of stress: physiological stress markers such as blood glucocorticoid concentration, glucocorticoid concentration in hair, feathers, and faeces; behavioural stress markers such as flight initiation distance, vigilance frequency, and altered activity budgets; and ecological context including proximity to settlement edges, habitat fragmentation, and duration of exposure to stress. Each domain is evaluated together in one framework in order to create a standardized procedure to assess stress levels and define buffer zones and mitigation procedures. Peer-reviewed articles on animal science are used to back up each domain of evaluation.

* Corresponding Author's email: ku.ratnasonekar@kalingauniversity.ac.in
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Introduction

The unending growth of development into natural habitat areas has exposed wildlife to a sustained period of close contact with humans. This exposure has resulted in a variety of human-induced stresses for the animal, including noise, artificial lighting, vehicular movement, recreation, and exposure to other humans, domestic animals, and livestock (Iglesias-Carrasco et al., 2020). Such chronic stress may impact an animal's physiology and reproduction, resulting in a change to its natural behaviour, making the animal vulnerable to loss of population stability within the affected habitat area (Mirante et al., 2025). Physiological and behavioural indicators have been used by animal scientists and conservation physiologists for a long time in assessing stress in wild animals. Physiological indicators include internal hormone levels such as glucocorticoids like cortisol and corticosterone, while behavioural indicators involve changes in the animal's behaviour such as escape distance and vigilance. While each approach has its benefits and shortcomings, the former is invasive due to capture and handling effects, whereas the latter does not require invasive procedures (Iglesias-Carrasco et al., 2020; Nepali et al., 2024).

Though a plethora of information has been gathered on individual stress indicators, there is still a necessity of having an integrative evaluative system that would take into account physiological, behavioural, and ecological data in a way relevant to animals living adjacent to human settlements, rather than to the anthropogenic disturbance occurring in the wider landscape. This paper aims to fill the niche by suggesting the Wildlife Emotion Framework an animal science evaluative system based on valid field and laboratory techniques developed in the sphere of wildlife endocrinology and behavioural ecology. The term "emotion" here means an affective state of an animal as a subject of animal welfare science, which is revealed with the help of valid physiological and behavioural markers of that state, which is a usual convention in animal welfare and conservation physiology studies (Mirante et al., 2025; Mayer et al., 2019).

Key Contributions

- Provides a holistic framework for measuring the stress responses of wildlife around human establishments.
- Integrates physiological, behavioural, and ecological information into a comprehensive and cohesive animal science-based measurement technique.
- Suggests standardization of stress measurements to aid conservation planning and wildlife monitoring.

The rest of this paper is structured as follows. Section 2 deals with the physiological foundation for stress assessment. Section 3 deals with behavioural stress indices, Section 4 deals with the integrated approach and ecological perspective, Section 5 provides an overview of applications, and Section 6 concludes this paper.

Physiological Basis of Stress Evaluation

Hypothalamus-Pituitary-Adrenal (HPA) Axis, or hypothalamus-pituitary-interrenal (HPI)

axis in birds and reptiles, controls the secretion of glucocorticoid hormones in response to a stressor stimulus. The level of glucocorticoids has been traditionally accepted throughout animal studies as an indirect measure of physiological stress load, or the amount of effort required by an animal to mobilize energy resources in response to a disruption (Mirante et al., 2025). Methods for measuring glucocorticoid levels have evolved considerably over recent decades. Although blood sampling from plasma provides an indicator of acute stress responses, it is an invasive method and may produce erroneous results due to the effect of handling on the level of stress hormones. In contrast, hair or claw cortisol sampling, applicable for a number of wild mammals, reveals a long-term (over weeks/months) pattern of hormone deposition, being much less affected by the process of sampling itself (Fokidis et al., 2023). Faeces and urine glucocorticoid metabolites can be used for non-invasive measurements as well.

Physiological assessment is considered to be the evidentiary basis in the Wildlife Emotion Framework. Chronic sampling methods, like cortisol from hair or claws, should be used for the determination of stress due to the settlement because they provide exposure on a biologically relevant time scale and not the capture of one particular disturbance event. It was shown in recent meta-analysis synthesis of various terrestrial vertebrates that glucocorticoid response after anthropogenic disturbance differs substantially depending on the type of disturbance and species-specific life history characteristics (Iglesias-Carrasco et al., 2020), which is highly relevant for the framework as it includes physiological assessment along with ecological context, as explained in Section 4.

Behavioural Indicators of Stress

Behavioural measures constitute an alternative and non-intrusive form of evidence that can be gathered by direct observation without ever handling or capturing the animal in question. The concept of flight initiation distance (FID) which refers to the distance between an approaching human and the animal when escape starts is one of the best-validated examples of a behavioural indicator of perceived threat in wildlife (Livezey et al., 2016; Mayer et al., 2019). Several field studies carried out on birds have shown that FID correlates systematically with distance from human habitation, although this correlation may not always be linear, with some species habituating to people at very short distances and others becoming wary at medium distances (Bjørvik et al., 2015). Similar approaches to measuring escape distances have also been used for waterbirds, raptors, and small mammals (Mayer et al., 2019).

In addition to FID, the approach also includes additional behavioural metrics such as vigilance rate (the proportion of time spent looking out for dangers compared to foraging or resting), activity budget perturbation (deviation from baseline allocation of time to feeding, resting, and moving), and avoidance behaviour (displacement from settlement boundaries in times of peak human presence). These variables are gathered using a well-known technique for behavioural observation based on standardized ethograms and focal animal sampling. The combination of

FID with vigilance and activity budgets makes it possible for the approach to differentiate between temporary alarm reactions and behavioural perturbation, the latter being more likely linked to fitness consequences.

Ecological Context and Framework Integration

Physiological and behavioural measures will have no meaningful interpretation outside of the ecological context within which they were taken. Thus, the Wildlife Emotion framework includes a third evaluation measure that consists of settlement distance gradient, habitat fragmentation index, disturbance rate, and season or life history stage at time of evaluation. Studies of urban and rural vertebrate communities show that the association between human proximity and stress physiology is variable; a large-scale meta-analysis of glucocorticoid responses along an urban gradient shows that there was no evidence for an elevated level of stress hormones in urban vertebrates, implying that habituation, resource availability, and absence of predators may alleviate the physiological cost of being close to humans in some species and environments (Nepali et al., 2024).

In the integrated approach, the general assessment of stress in animals is achieved by taking into account the combination of the three areas rather than through a combined score. The presence of increased levels of chronic glucocorticoids, decreased FID, and heightened vigilance, as well as proximity and regular association with settlements, points to a high level of stress and need for intervention. On the other hand, constant levels of hormones along with constant, species-typical behaviour in relation to settlements can be an indication of proper habituation rather than chronic stress. This combined approach has a long history in conservation physiology, as single-parameter assessments are unreliable (Mirante et al., 2025; Iglesias-Carrasco et al., 2020).

Applications and Species Considerations

Adaptability of the framework rather than prescriptiveness of any specific protocol for sampling is an underlying principle of the proposed framework rather than a protocol prescription for sampling. For mammals, glucocorticoids sampled from hair or claws along with camera trap vigilance scoring is suggested using the validated protocols designed for the European badger (Fokidis et al., 2023). For birds, glucocorticoid metabolites in faeces along with measurements of flight initiation distance can be used as minimally invasive sampling procedures suitable for use around settlements using validated escape-distance approaches for waterbirds and passerines (Livezey et al., 2016; Mayer et al., 2019). For species living in floodplain, agricultural or peri-urban landscapes where the distance to settlements is variable on a continuous scale, the ecological context domain should involve fine-scaled distance gradient rather than a simple rural/urban binary categorisation based on findings that behaviour in relation to settlements tends to be best modelled by piecewise and non-linear distance effects (Bjørvik et al., 2015).

Implementation of the framework in field-based studies entail three successive steps: setting up a baseline through an undisturbed site, comparative sampling at increasing distances from human habitation, and longitudinal sampling in different seasons to factor in life history effects on baseline hormone concentrations and behaviour. The three-step process emulates existing conservation physiology protocols and guarantees that assessment of stress in proximity to human habitation is done using a scientifically justified baseline instead of an isolated one.

Conclusion

Animals residing around areas where humans reside are subject to a unique set of stressors that demand an evaluation strategy which incorporates physiological, behavioural, and ecological approaches to evaluating stress. This paper presents the framework called Wildlife Emotion that brings together proven methods from animal science literature that have been published and peer reviewed, such as glucocorticoid endocrinology, behavioural ecology, and ecological analysis of habitat, to form an analytical framework for measuring the severity of stress in animals around human settlements. This framework enables a scientific understanding of how to prioritize and conduct conservation activities around mitigating these stresses, designing buffer zones for human settlements, and monitoring the welfare of animals living in and around human settlements through the combination of the three evaluation domains.

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