Behavior of Sumatran Tigers (*Panthera tigris sumatrae*) at Ragunan Zoo and the Development of an E-Magazine as Biology Learning Media for Senior High School Students

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Abstract: The Sumatran tiger (*Panthera tigris sumatrae*) is critically endangered due to poaching and habitat loss, yet learning media based on authentic behavioral data are limited. This research and development study aimed to observe the behavior of captive Sumatran tigers and integrate the findings into a digital biology e-magazine. Observations were conducted at Ragunan Zoo, Jakarta, over 14 days (December 2023–January 2024), totaling 84 hours. The subjects were a 13-year-old male and a 15-year-old female tiger, observed using focal animal sampling and continuous recording during two daily sessions (08:00–12:00 and 13:00–15:00 WIB). Behaviors were categorized into resting, locomotion, social interaction, elimination, and other activities. Resting behavior dominated the activity budget of both tigers (male: 50.56%; female: 49.05%), which is typical for captive carnivores and influenced by enclosure conditions and daytime heat. Social interaction and elimination were the least frequently observed behaviors. The behavioral results were used to develop a digital e-magazine through analysis, design, validation, and revision stages. Product feasibility was evaluated using Likert-scale questionnaires completed by three expert validators and four senior high school biology teachers. The validation results indicated high feasibility, with expert and teacher scores of 93.3 percent and 85 percent, respectively, suggesting strong potential for classroom application. This study demonstrates that ex-situ behavioral data can be transformed into accessible digital learning media to support biodiversity education and conservation awareness aligned with SDG 15. Nevertheless, behavioral interpretations should be considered preliminary, as observations were limited to two captive individuals and learning outcomes were not assessed.

Introduction

The Sumatran tiger (*Panthera tigris sumatrae*), an apex predator native to Sumatra, is listed as Critically Endangered by the IUCN and included in Appendix I of CITES, highlighting the urgent need for coordinated conservation action (1). Its numbers continue to fall due to habitat loss, poaching, conflict with humans, and illegal trade (2). Approximately 400 Sumatran tigers are estimated to remain in the wild under in-situ conservation management. Meanwhile, the ex-situ population in Indonesia consists of 127 individuals, and an additional 244 individuals from other tiger subspecies are recorded in global captive breeding programs (3). This situation places the Sumatran tiger at considerable risk and threatens the ecological balance of its native forests. As a top predator, it helps regulate prey populations and maintain habitat health, and its disappearance could accelerate ecosystem decline (4). Both in-situ and ex-situ institutions contribute to efforts to prevent extinction.

Facilities such as Taman Margasatwa Ragunan (TMR) serve as centers for breeding, research, and public education, yet systematic studies documenting Sumatran tiger behavior in these settings are still limited. Existing research on captive large carnivores has highlighted the importance of activity budgets, environmental enrichment, and welfare indicators, but similar work specific to Sumatran tigers in Indonesia remains scarce (5). This gap is noteworthy because behavioral observations are essential for welfare assessment and for improving husbandry and management strategies.

Compared to managed populations of Bengal or Amur tigers in North America and Europe, where enrichment standards and long-term breeding programs are well established, documentation of Sumatran tiger behavior in

captivity remains limited. This highlights a global gap in species-specific husbandry knowledge.

In the educational context, Indonesian senior high school curricula emphasize biodiversity, ecological interactions, and conservation. However, students often rely on text-heavy materials that lack local, research-based examples of wildlife behavior. Interactive digital media, including e-magazines, have shown potential to support engagement and understanding, yet few are developed using primary behavioral data from native species such as the Sumatran tiger ([6]). This creates a clear link between the conservation crisis and the need for innovative learning media grounded in empirical observations of local wildlife.

Although some studies have examined tiger behavior in captivity, detailed activity patterns of Sumatran tigers in Indonesian ex-situ facilities remain poorly documented. Even more limited are efforts to translate such behavioral data into accessible digital learning resources for high school biology. This gap forms the core problem addressed by the present study, which seeks to combine behavioral research with the development of educational media.

The present study observed and described the behavioral activities of two Sumatran tigers housed at TMR and used the findings to develop an interactive biology e-magazine through a research and development approach. The media produced was then validated by experts and high school biology teachers to determine its feasibility for classroom use. The study is limited to behavioral observation, media development, and validation; it does not assess student learning outcomes, compare individuals across institutions, or examine physiological indicators of welfare. By defining this scope, the research aims to contribute meaningful behavioral data relevant to ex-situ management while offering a validated educational resource aligned with national curriculum goals, SDG 4 on quality education, and SDG 15 on life on land.

Methodology

Time and Location of Study

This study was conducted at Taman Margasatwa Ragunan (TMR), located on Jalan Harsono RM No. 1, Ragunan, Pasar Minggu, South Jakarta. Behavioral observations of two Sumatran tigers were carried out over 14 days between December 2023 and January 2024. The entire research process, including preparation, behavioral observation, media development, validation, and reporting, took place from October 2023 to July 2024.

Research Method

A qualitative descriptive observational design was employed to document and characterize the behavioral activities of Sumatran tigers in captivity. Focal animal sampling was applied by continuously monitoring one individual during each observation session, following the methodological guidelines established by Altmann (1974). This continuous recording approach enabled all behaviors exhibited by the tigers to be documented in real time, providing a comprehensive and detailed representation of their activity patterns across the observation period.

In addition to direct behavioral observations, environmental conditions such as weather, enclosure characteristics, and time of day were monitored to support the interpretation of daily and contextual variations in behavior. Structured interviews with animal keepers were

also conducted to provide supplementary information regarding feeding routines, management practices, and individual behavioral tendencies. The overall approach emphasized descriptive analysis rather than statistical inference, and any comparisons made between individuals or observation periods were exploratory in nature, reflecting the very small sample size and the study's focus on qualitative behavioral characterization.

Materials and Instruments

Tools used during field observations included tally sheets for structuring recorded behaviors, stationery for manual notation, a wristwatch for time control, a Canon EOS 1500D digital camera for documentation, and a ThermoPro TP50 digital hygrometer for monitoring temperature and humidity throughout the day. For the development of the digital learning media, a Lenovo IdeaPad laptop was used to design the e-magazine layout with Canva, and Heyzine Flipbook was employed to transform the PDF draft into an interactive digital format. These instruments supported consistency, clarity, and replicability in both data collection and media development.

Population and Sample

The population of this study consisted of twenty Sumatran tigers housed at TMR. Two individuals were selected through purposive sampling based on visibility, health condition, and consistent enclosure availability during the study period. The selected subjects were a thirteen-year-old male named Kola and a fifteen-year-old female named Hana. Although a two-individual sample aligns with ethological practices for intensive behavioral observation, it limits the generalizability of the findings. This limitation is acknowledged explicitly as part of the methodological constraints of the study.

Variables and Operational Definitions

The behavioral variables observed included resting, locomotion, social interaction, elimination, and other individual behaviors such as grooming, drinking, and swimming. Each category included observable actions that were recorded based on continuous monitoring. Environmental variables consisted of temperature and humidity, measured hourly using the hygrometer, to explore qualitative relationships between environmental shifts and changes in behavioral patterns. For media validation, variables included content feasibility, media design quality, and linguistic clarity, all assessed using Likert-scale questionnaires completed by experts and teacher respondents.

Operational Ethogram of Sumatran Tiger Behavior

To ensure consistency and replicability in behavioral observations, an operational ethogram was developed as a standardized reference for behavior coding. The ethogram provides clear operational definitions for each behavioral category, enabling systematic and objective recording while reducing observer bias and improving data reliability. The use of this ethogram facilitated consistent data collection across observation sessions and periods. The behavioral categories and definitions used in this study are presented in **Table 1**. The ethogram was adapted from previous studies and refined through preliminary observations at Ragunan Wildlife Park. This process allowed inclusion of site-specific behaviors while maintaining frameworks. The ethogram supported data validity and comparability.

Table 1. Operational definitions of Sumatran tiger behavioral categories.

No	Behavior Category	Operational Definition
1	Resting	Any inactive position without forward movement, including lying down, sitting, or sleeping for ≥10 s. Includes sleeping, lying down, and sitting in a calm state.
2	Locomotion	Any active movement that causes displacement from one location to another, including walking, pacing, climbing, or jumping. Pacing is defined as the behavior of walking repeatedly along the same path at least three times in a row.
3	Social Interaction	Any form of interaction involving another tiger or keeper, including vocalization, head rubbing, paw contact, or behavioral responses directed toward other tigers or humans.
4	Elimination	Behaviors related to excretion, including urination and defecation, were identified based on body posture and specific marking patterns.
5	Other Behaviors	Individual behaviors not included in the above categories, such as grooming (licking or rubbing parts of the body), drinking, swimming, or soaking in a pool of water.

Data Collection Methods

Behavioral data were collected through continuous focal animal sampling in two daily sessions from 08.00–12.00 and 13.00–15.00 WIB (Western Indonesian Time) over fourteen days. Each tiger was observed in seven sessions, resulting in balanced coverage of morning and afternoon activity patterns. Observers maintained consistent positions near the exhibition enclosures and recorded behavioral occurrences on structured tally sheets. The study did not employ multiple observers, and therefore, inter-observer reliability data were not generated. This limitation is acknowledged. Interview with keepers provided complementary insights on enclosure routines, feeding schedules, and individual histories. Temperature and humidity were measured hourly throughout observations using the digital hygrometer. Total observation h per individual were determined by the fixed daily schedule, and all monitoring focused on daytime activity.

Observer Training and Observation Consistency

Before formal data collection, the observer underwent a preparatory training phase to ensure consistency in behavioral recording. This training included: (1) reviewing relevant literature on tiger ethology and captive behavior; (2) studying the predefined ethogram and its operational definitions; and (3) conducting preliminary trial observations outside the main data collection period to familiarize the observer with the focal animal sampling and continuous recording techniques.

During the training phase, trial observations were compared against the ethogram definitions to minimize ambiguity in behavioral categorization. Although the study involved a single observer and therefore did not allow for inter-observer reliability testing, this preparatory phase was intended to reduce observer bias and increase internal consistency in behavioral coding. This limitation is acknowledged, and future studies are encouraged to involve multiple trained observers to enable reliability testing.

Research Design

The behavioral component of the research followed a descriptive observational design. The media development component adopted a research and development (R&D) approach modeled after the general framework of Borg and Gall, adapted into stages that included information gathering, preliminary design, drafting, expert validation, revision, and dissemination. This design ensured that behavioral data served directly as the empirical foundation for the e-magazine content.

Observation Procedures

Each observation session followed established guidelines for focal sampling, where one tiger was continuously monitored during a fixed time period. All behaviors were documented in real time. Observers maintained stable positions at a safe distance to avoid disturbing the animals, and all observations were conducted outside feeding and enclosure-cleaning times to prevent interference. The study did not involve physical contact, manipulation, or interference with the animals, and therefore complied with minimal-risk practices for behavioral research in captive settings.

Data Analysis

Behavioral data were analyzed descriptively by calculating the frequency of each behavior category and the relative frequency following the methodology proposed by Martin and Bateson (1994). The total frequency of observed behaviors was calculated by summing the frequencies of all recorded behavior categories (**Equation 1**), and the relative frequency for each behavior category was subsequently calculated as the proportion of its frequency relative to the total frequency of all observed behaviors, multiplied by 100%. This approach generated descriptive summaries of individual activity budgets. Inferential statistical analyses were not conducted due to the limited sample size (n = 2), which was insufficient to satisfy assumptions of sample adequacy, independence, and generalizability. With only two individuals observed, any statistical comparison would be unreliable and potentially misleading. Therefore, comparisons between individuals and between observation periods were interpreted qualitatively and framed as exploratory rather than conclusive. Questionnaire data obtained from experts and teachers were converted into feasibility percentages by dividing the total score obtained by the maximum possible score and multiplying by 100%. Measures of internal consistency (Cronbach's alpha) and inter-observer reliability were not calculated, and this limitation is acknowledged as a methodological constraint of the study.

$$F = Sum\ F_i;\ RF_i = (F_i\ /\ F)\ x\ 100\%.$$

Equation 1 | F = total frequency, F_i = frequency of the *i*th behavior, RF_i = relative frequency.

Development Procedure of the Learning Media

The biology e-magazine was developed based on the behavioral findings obtained from the field. Information was organized into a structured storyboard that guided the layout and content flow. Canva was used to prepare the design, and the final draft was formatted as a PDF before being converted into an interactive flipbook through Heyzine. The design incorporated images, visuals, and concise explanations aligned with high school biology competencies on biodiversity and behavioral ecology.

Validation and Revision

The e-magazine underwent validation by subject matter experts, media design experts, and language experts, followed by evaluation from senior high school biology teachers. Validators assessed the media in terms of content accuracy, instructional relevance, visual design, interactivity, and linguistic clarity using structured Likert-scale instruments. Language revisions were conducted to ensure consistency with standard academic English conventions, including clarity, coherence, grammatical accuracy, and appropriate scientific terminology. Revisions were implemented based on both quantitative scores and qualitative feedback provided by the validators.

Research Ethics

This study was conducted with formal permission from Taman Margasatwa Ragunan (TMR), Jakarta, and adhered to established animal welfare guidelines for non-invasive behavioral research in captive wildlife settings. All observations were carried out during routine exhibition h and focused solely on naturally occurring behaviors. The research involved no physical contact, manipulation, feeding intervention, or alteration of enclosure conditions.

Because the study relied exclusively on observational data and did not involve experimental treatment or invasive procedures, formal approval from an institutional animal ethics committee was not required under the applicable institutional regulations. Nevertheless, ethical principles of animal welfare were strictly observed by minimizing disturbance to the animals and ensuring that all recorded behaviors occurred naturally.

For future studies involving experimental manipulation, physiological sampling, or prolonged disturbance, formal ethical clearance from an accredited animal ethics committee would be required and is strongly recommended.

Methodological Limitations

This study acknowledges several limitations, including the very small sample size of two individuals, the restricted observation period of fourteen days, the exclusive focus on daytime activity, the absence of inter-observer reliability data, and the lack of a statistical reliability index for validation questionnaires. Media validation involved a small number of respondents, and the effectiveness of the e-magazine on student learning outcomes was not tested. These limitations affect the generalizability and depth of interpretation but do not undermine the descriptive and developmental goals of the research.

Potential observer bias may have influenced the behavioral records because all observations were conducted from fixed viewing points outside the enclosures. Some areas were partially obstructed by vegetation or enclosure structures, which may have caused under-recording of certain behaviors. Additionally, because data collection occurred only during daytime exhibit h, nocturnal or crepuscular behaviors, which are natural in wild tigers, were not captured. These factors limit the representativeness of the activity budget.

Result

Behavioral observations of the two Sumatran tigers were conducted over a two-week period from 23 December 2023 to 13 January 2024 at Taman Margasatwa Ragunan (TMR). The observations focused on two individuals housed in exhibition enclosures: Kola, a 13-year-old male, and Hana, a 15-year-old female. The results are presented descriptively, as no inferential statistical analyses were applied. Accordingly, differences between individuals and across observation h should be interpreted as exploratory patterns rather than statistically tested comparisons.

Overall behavioral proportions of both individuals are presented in **Figure 1A**, providing an overview of resting, locomotion, social interaction, elimination, and other behaviors. The figure serves as a visual summary, while the accompanying narrative describes observable trends without implying statistical significance. Across the observation period, resting was the most frequently recorded behavioral category in both tigers, followed by locomotion. Sleeping constituted the largest proportion of resting behavior in both the male (26.55 percent) and the female (24.48 percent).

Locomotion was predominantly characterized by regular movement, accounting for 33.93 percent in the male and 33.25 percent in the female, whereas pacing occurred only minimally in both individuals. Social interactions were infrequent, with the male primarily interacting with keepers and the female occasionally interacting with other tigers. Urination was observed more frequently than defecation in both individuals. Among behaviors classified as "other," grooming was the most dominant, representing 7.50 percent in the male and 7.34 percent in the female. These variations reflect individual behavioral differences rather than statistically tested distinctions.

Hourly activity patterns are summarized in **Figure 1B**, which illustrates the distribution of behavioral frequencies across morning and midday observation periods. Both individuals exhibited the highest activity levels between 09:00 and 10:00 WIB and the lowest between 11:00 and 12:00 WIB. This pattern corresponds with changes in environmental parameters recorded during the observation period.

Although no statistical testing was conducted to evaluate the relationship between behavior and environmental variables, the observed descriptive trends are consistent with previous findings indicating that large felids tend to reduce activity during hotter periods. Overall, these results provide an initial characterization of daily activity rhythms of Sumatran tigers in this ex-situ conservation setting.

Educational Application of Research Findings

In accordance with the objectives of this study, the behavioral data collected from the two Sumatran tigers were developed into a digital biology learning medium in the form of an e-magazine. The structure of the e-magazine is presented in **Table 2**, which outlines the main sections, including introductory content, core learning materials, and supporting components such as a glossary and references.
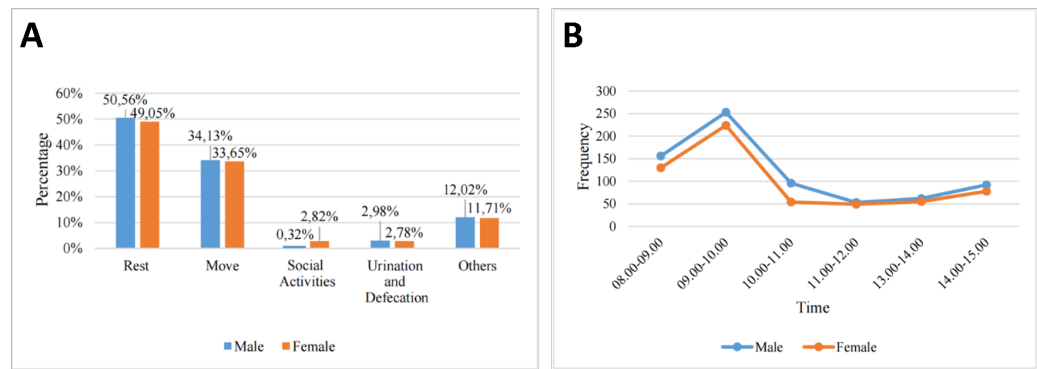
Figure 1. Behavioral Patterns of the two Sumatran tigers: Overall behavioral proportions (A) and hourly activity distribution (B).

Table 2. Structure of the E-Magazine.

No.	Section	Description
1	Front Cover	Contains the title of the e-magazine, logos of Pakuan University, Ragunan Zoo, Kampus Merdeka, and the author's name.
2	Introduction	Includes the foreword, table of contents, and learning objectives.
3	Main Content	Covers core materials such as biodiversity, conservation status of Sumatran tigers, habitat and distribution, classification and morphology, mating behavior, Ragunan Zoo, research findings, and conservation efforts.
4	Conclusion	Presents a summary, references, glossary, and author biography.
5	Back Cover	Features the logo of Pakuan University and the name of the Biology Education Study Program, Faculty of Teacher Training and Education.

The e-magazine integrates the research findings into an accessible and visually engaging educational resource that is aligned with curriculum requirements and defined learning objectives. The presentation of scientific content in a digital magazine format enhances readability and learner engagement, making complex research outcomes more approachable for students at different learning levels.

The content is designed to facilitate students' understanding of animal behavior concepts through the use of real observational data obtained from field-based research. By incorporating authentic data, the e-magazine enables learners to connect theoretical concepts with empirical evidence, thereby strengthening conceptual comprehension and fostering scientific reasoning skills.

In addition, the e-magazine promotes independent learning by encouraging students to explore, analyze, and interpret information at their own pace. The contextualized presentation of animal behavior within real-life settings supports the development of scientific literacy, critical thinking, and inquiry-based learning, which are essential competencies in science education.

Furthermore, the digital format of the e-magazine allows for flexible implementation in both classroom-based and remote learning environments. Its adaptability supports diverse teaching strategies and learning modalities, making the e-magazine a practical and effective instructional resource for modern educational contexts.

Feasibility Assessment of the Learning Media
The e-magazine was evaluated through an expert validation process involving content, media, and language experts, as well as one high school biology teacher as a respondent. The validation focused on content accuracy, visual and structural design, and language clarity, and was intended to assess feasibility rather than instructional effectiveness. During the first validation stage, the media expert recommended revisions to improve clarity and completeness, including adding the research location to the title, revising learning objectives using the ABCD model, shortening the biodiversity video, and incorporating material on levels of biodiversity. Revisions were also made to the tiger behavior section by aligning numerical references with graphs and replacing photographs with videos. In addition, the back cover was enhanced with illustrative elements. The language expert suggested improvements related to spelling, punctuation, sentence clarity, and consistency with standard academic English.

All recommendations provided by the validators were incorporated into the revised version of the e-magazine. Following these revisions, substantive improvements were evident across multiple aspects of the product, including title modification, refinement of learning objectives, adjustment of multimedia content, enhancement of the overall layout, the addition of a glossary, and the inclusion of an illustrated back cover, as illustrated in **Figure 2**.

These revisions were intended to improve both the pedagogical quality and visual appeal of the e-magazine, ensuring greater alignment with learning objectives and user needs. The enhanced structure and supporting features were designed to facilitate clearer concept delivery, improve navigation, and increase student engagement with the learning material.

After the revision process, the e-magazine underwent a second validation by the same expert groups to evaluate the effectiveness of the implemented improvements. The expert validation results are presented in **Figure 3A**, while the respondents' validation scores are shown in **Figure 3B**, providing an assessment of the e-magazine's feasibility and suitability as an educational resource.

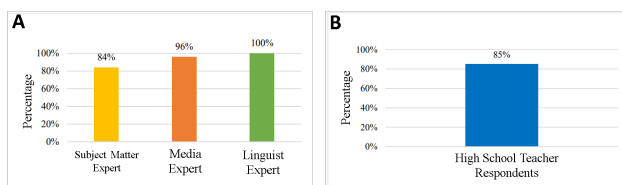**Figure 2.** Revisions to the E-Magazine Based on Expert Suggestions.

Figure 4. Behavioral activities, enclosure conditions, and management practices of Sumatran tigers at Ragunan Zoo: resting behavior (A–B), locomotion behavior (C–G), social interaction (H), grooming behavior (I), bathing behavior (J), drinking behavior (K), sleeping enclosure (L–M), exhibition enclosure (N), drainage system (O), and cleaning activity (P). Source: Author's documentation (2024).

Figure 3. E-Magazine validation score (A) and respondents' validation score of the E-Magazine (B).

Discussion

Resting Activity of Sumatran Tigers

Resting behavior in Sumatran tigers is characterized by limited physical activity, including sitting, lying down, and sleeping (7). Observations at Ragunan Zoo showed that the tigers frequently sought shaded areas, such as under trees or inside artificial caves, particularly during periods of intense sunlight. Sleeping was the most dominant resting behavior, functioning primarily to restore energy (8), as shown in **Figure 4A** –**B**.

In this study, differences observed between the male and female tigers represent descriptive tendencies, as no inferential statistical tests were conducted. The male tiger displayed a higher proportion of resting behavior, likely related to its greater locomotor activity, which requires longer recovery. Resting behavior peaked during the afternoon when temperatures reached 31–32°C. This pattern aligns with Hamdani *et al.* (2022), who noted that high ambient temperatures tend to reduce activity levels in captive tigers (9).

Furthermore, the activity pattern observed here corresponds with the reported optimal temperature range for Sumatran tigers (24–27°C) (6). The species is naturally more active at night, when cooler temperatures are conducive to movement (10).

Movement Activities of Sumatran Tigers

Locomotor activity refers to movements such as walking, pacing, and climbing (7). In this study, regular walking was more frequently observed than pacing. Walking behavior involved movement throughout the enclosure, whereas pacing involved repetitive locomotion within a fixed area, as shown in **Figure 4C**–**G**.

As with resting behavior, differences between the two individuals are descriptive and explorative, not statistical. The male tiger showed more movement, which is consistent with the species' larger home-range size in the wild (11). The highest movement frequency occurred in the morning, likely because the tigers explored the newly opened exhibit area after being released from the sleeping enclosure (10).

The proportion of walking was much higher than pacing. However, instead of concluding the absence of stress, the results are better interpreted as "no strong indication of visitor-induced stress was detected." This is because both tigers were captive-born and accustomed to visitors (12).

Social Activities of the Sumatran Tiger

Social activities included interaction with other tigers, keepers, and visitors (7). Interaction between tigers was only observed among females, facilitated by a connecting barred gate (13). Behaviors included head rubbing and gentle pawing. The male vocalized frequently, which aligns with the "meeting call".

Interaction with keepers occurred during cleaning sessions, where the tiger responded through vocalization. No interaction with visitors was recorded, likely due to distance and habituation. Again, these findings represent observational tendencies rather than statistical comparisons (14).

Urination and Defecation Behavior of the Sumatran Tiger

Urination and defecation behaviors were recorded in consistent locations, aligning with territorial marking behavior (12). Temperature appeared to influence urination frequency: urination increased at lower temperatures and decreased under higher heat (15), as shown in **Figure 4J**–**K**. These relationships are described descriptively, as no statistical correlation analysis was performed.

Other Activities of the Sumatran Tiger

Grooming involved licking and rubbing body parts, typically during rest periods (16). As expected for a solitary species, only autogrooming was observed. Drinking behavior increased during hot weather, and males drank more frequently, consistent with higher overall movement levels (7). Bathing occurred in the shallow pool during heat periods, a thermoregulation strategy also observed in wild tigers (17), as illustrated in **Figure 4I** and **Figure 4L**–**M**. These observations are preliminary descriptive findings, given the small sample size (n=2).

Enclosure Design for Sumatran Tigers at Ragunan Zoo

Enclosures are essential components of ex-situ conservation, particularly for species with large spatial and behavioral requirements such as the Sumatran tiger. Ragunan Zoo (TMR) maintains two exhibition complexes, each comprising sleeping enclosures (off-exhibit) and display enclosures (on-exhibit), see as shown in **Figure 4N** and **Figure 4O**. A total of 17 sleeping enclosures are available, 8 units at the first site (3 × 2.5 m²) and 9 units at the second site (6 × 3 m²) (18). Each is equipped with a raised concrete resting platform and a water trough to meet basic welfare needs. While these facilities provide essential shelter and nighttime holding space, their limited size relative to natural home ranges may influence locomotor and exploratory behavior, and such spatial constraints should be considered when interpreting the behavioral patterns observed in this study.

Exhibition Enclosures for Sumatran Tigers at Ragunan Zoo

Exhibition enclosures are open-air spaces where Sumatran tigers engage in daily activities from morning to late afternoon. These enclosures are designed to resemble the tigers' natural habitat and are intended to house one individual per unit. At Ragunan Zoo (TMR), the first site features two open enclosures measuring 50 × 20 m², while the second site contains four enclosures averaging 20 × 16 m², with varying layouts and structural configurations. Each exhibition enclosure features artificial habitat elements, including trees and man-made caves for resting, logs for claw sharpening, and a water pool for drinking and bathing. The pools are more than 1.5 meters deep, serving a dual function as enrichment and as a barrier to prevent escape.

Cleaning Procedures for Sumatran Tiger Enclosures at Ragunan Zoo

Cleaning of the Sumatran tiger enclosures at Ragunan Zoo (TMR) is conducted daily. The cleaning of sleeping enclosures involves removing feces and food remnants, followed by spraying the floor with clean water using a hose and scrubbing it thoroughly with disinfectant. Each sleeping enclosure is equipped with a drainage system that allows waste water to be disposed of efficiently by the zookeepers. The exhibition enclosures are maintained by removing fallen leaves, weeds, and other debris. Tree pruning is also carried out when branches are deemed potentially hazardous to the tigers see **Figure 4P**.

Environmental Parameters Affecting Sumatran Tiger Activity

The activity frequency of Sumatran tigers is influenced by environmental factors such as temperature and humidity. Tigers tend to be more active in the early morning when temperatures are lower. As the temperature rises toward midday, activity levels decrease, with tigers spending more time resting. This pattern aligns with Dewi *et al*. (2021), who found that high daytime temperatures lead tigers to increase resting behavior (10).

At Ragunan Zoo (TMR), the temperature within the tiger exhibition enclosures ranged from 26°C to 32°C, with humidity levels between 76% and 86%. According to Yolanda *et al*. (2017), the optimal temperature range for tiger activity is between 24°C and 27°C, with natural humidity levels typically ranging from 86% to 95% (5).

Behavioral Differences of Sumatran Tigers in In-situ and Ex-situ Conservation Areas

Environmental differences between in-situ (natural habitat) and ex-situ (captivity) conservation settings result in notable behavioral variations in Sumatran tigers, particularly in movement, resting, and social activities. In captivity, movement is significantly limited due to spatial constraints, whereas in the wild, tigers roam extensively for hunting. Male tigers typically have larger territories than females, with ranges reaching 60–100 km² compared to around 20 km² for females (11). Resting behavior dominates in captivity, in contrast to the wild, where active movement is more prevalent. According to Alfila and Radhi (2019), wild tigers engage in frequent movement to hunt, which is essential for their survival and directly linked to their expansive home ranges (8). Social behavior is also more restricted in captivity. While Sumatran tigers are naturally solitary, except during mating season or when females rear cubs, captive individuals cannot choose mates freely (7). Breeding programs often avoid pairing certain individuals to prevent inbreeding, leading some tigers to miss reproductive opportunities until suitable mates from other facilities are introduced. In the wild, mate selection occurs naturally and freely.

Sumatran Tiger Conservation in In-situ and Ex-situ Settings

The Sumatran tiger (*Panthera tigris sumatrae*) continues to face a population decline due to widespread poaching and illegal trade. As a result, the species is listed as *Critically Endangered* by the IUCN (2008) and included in Appendix I of CITES, which prohibits all forms of commercial trade (1, 19). Conservation efforts are crucial in preventing extinction, guided by principles of sustainable natural resource management.

In-situ conservation focuses on protecting biodiversity and forest ecosystems, involving community participation, enforcing anti-poaching patrols, and prosecuting illegal wildlife trade offenders within the tiger's natural habitat.

Ex-situ conservation involves captive breeding programs in zoological institutions to increase population numbers.

These programs also serve as a genetic reservoir and potential support for future reintroductions into the wild.

Educational Media Development: E-Magazine on Sumatran Tiger Behavior

The findings of this study were implemented in the educational field through the development of a digital learning media, an e-magazine, featuring the behavioral activities of Sumatran tigers at Ragunan Zoo. This medium supports the high school biology curriculum, particularly the biodiversity topic in Grade X, by aiming to increase students' understanding of animal behavior and conservation efforts.

The e-magazine underwent validation by experts in content, media, and language, achieving a high validity score of 93.3%. It was further assessed by high school teachers, receiving a score of 85%, which, based on Arikunto's (2016) classification, indicates the product is highly valid for classroom use (20). These results are consistent with those of Fuad *et al*. (2020), who demonstrated that e-magazines effectively enhance biology learning efficiency and engagement (21).

The e-magazine is expected to support the development of conservation awareness and conceptual understanding among students, in alignment with SDG 15: Life on Land, which emphasizes ecosystem protection, sustainable land use, and biodiversity conservation (22).

Its strengths lie in its attractive and colorful design, multimedia integration (images and videos), and student-friendly language, which improve comprehension and engagement (23). However, its limitation is its dependency on electronic devices and specific software (e.g., Adobe Acrobat) to access PDF-based content (24).

Conclusion

This study descriptively analyzed the behavior of two Sumatran tigers (Kola, male; Hana, female) at Ragunan Zoo and developed an e-magazine for senior high school biology. Resting emerged as the most frequent behavior, followed by locomotion, while social interactions were limited. Urination occurred more often than defecation, and grooming dominated other behavioral categories. Peak activity occurred between 09:00–10:00 WIB and was lowest between 11:00–12:00 WIB, showing a descriptive relationship with temperature and humidity. These findings reflect individual variation and enclosure-specific conditions rather than population-level trends.

The study presents novel ethological data on ex-situ Sumatran tigers, demonstrating the feasibility of integrating such observations into an educational digital medium. The e-magazine achieved high expert and teacher validity scores, indicating strong potential for classroom use, although its effectiveness on student learning outcomes was not assessed. Limitations include the small sample size, daytime-only observations, and the descriptive nature of the analysis.

Future studies should incorporate nocturnal observations, larger sample sizes across multiple zoological institutions, and automated behavioral recording technologies to produce more comprehensive and representative activity budgets. Additionally, classroom trials of the e-magazine are needed to evaluate its educational impact, usability, and potential to enhance conservation literacy in diverse learning environments.

Declarations

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Conflict of Interest
The authors declare no conflicting interest.

Data Availability
All data generated or analyzed during this study are included in this published article.

Ethics Statement
Ethical approval was not required for this study.

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