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Animal Welfare
New Insights

Edited by Shao-Wen Hung, Chia-Chi Chen,
Chung-Lun Lu and Tseng-Ting Kao

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Veterinary Medicine and Science

Volume 15

Aims and Scope of the Series

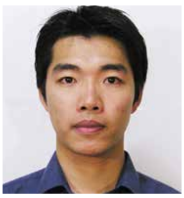
Paralleling similar advances in the medical field, astounding advances occurred in Veterinary Medicine and Science in recent decades. These advances have helped foster better support for animal health, more humane animal production, and a better understanding of the physiology of endangered species to improve the assisted reproductive technologies or the pathogenesis of certain diseases, where animals can be used as models for human diseases (like cancer, degenerative diseases or fertility), and even as a guarantee of public health. Bridging Human, Animal, and Environmental health, the holistic and integrative "One Health" concept intimately associates the developments within those fields, projecting its advancements into practice. This book series aims to tackle various animal-related medicine and sciences fields, providing thematic volumes consisting of high-quality significant research directed to researchers and postgraduates. It aims to give us a glimpse into the new accomplishments in the Veterinary Medicine and Science field. By addressing hot topics in veterinary sciences, we aim to gather authoritative texts within each issue of this series, providing in-depth overviews and analysis for graduates, academics, and practitioners and foreseeing a deeper understanding of the subject. Forthcoming texts, written and edited by experienced researchers from both industry and academia, will also discuss scientific challenges faced today in Veterinary Medicine and Science. In brief, we hope that books in this series will provide accessible references for those interested or working in this field and encourage learning in a range of different topics.

Meet the Series Editor

Rita Payan Carreira earned her Veterinary Degree from the Faculty of Veterinary Medicine in Lisbon, Portugal, in 1985. She obtained her Ph.D. in Veterinary Sciences from the University of Trás-os-Montes e Alto Douro, Portugal. After almost 32 years of teaching at the University of Trás-os-Montes and Alto Douro, she recently moved to the University of Évora, Department of Veterinary Medicine, where she teaches in the field of Animal Reproduction and Clinics. Her primary research areas include the molecular markers of the endometrial cycle and the embryo–maternal interaction, including oxidative stress and the reproductive physiology and disorders of sexual development, besides the molecular determinants of male and female fertility. She often supervises students preparing their master's or doctoral theses. She is also a frequent referee for various journals.

Meet the Volume Editors

Dr. Shao-Wen Hung is a veterinarian, researcher, and chief of the animal industry division. He is actively engaged in academic research in Taiwan, including cancer medicine, animal welfare, veterinary medicine, and fish disease. He has participated in research on antibacterial light-emitting diodes and the application and development of the Raman rapid detection method. He has published more than 120 journal papers, 130 conference papers, 12 patents, and 20 books. He has also served as a journal peer reviewer. Dr. Hung has successfully assisted animal drug factories and food factories to obtain animal drug and health food certificates.



Dr. Chung-Lun Lu graduated from the Institute of Fisheries Science, National Taiwan University, Taiwan, and is a researcher at Aquaculture Technology Research Center, Agricultural Technology Research Institute. Dr. Chung-Lun Lu is a pioneering researcher in aquaculture sciences. He published many papers and books in aquaculture science. He is actively engaged in academic research in Taiwan, including the development of high-value agricultural materials and assay platforms, etc.

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Contents

Preface

Animal welfare is a significantly important issue worldwide. However, the public's idea of animal welfare is usually formed from animal epidemic news or food scandals; it is not usually viewed as an urgent issue to be solved in the world.

Achievements made by scientists in the last several years have been exceptional, leading to major advancements in the fast-growing field of animal science. Experimental animals play a very important role in scientific research.

Pigs, rodents, and aquaculture animals are important experimental animals. To obtain accurate experimental data and meet the basic quality requirements of biological experiment materials, the experimental animals used should be specifically pathogen-free (SPF). These SPF animals are not only used to meet the demand for biomedical research but are also used to research and develop drugs and vaccines. Animal testing is an important verification stage before bringing it to market biomedical products.

As animal welfare has attracted attention in recent years, the most important issues to arise are reduced animal pain and quantity and increased experimental refinement, or what is referred to as the 3Rs of animal research (replacement, reduction, and refinement).

Animal Welfare - New Insights presents new insights, novel developments, current challenges, latest discoveries, recent advances, and future perspectives in the field of animal welfare.

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Section 1

Introduction

Chapter 1

Introductory Chapter: Animal Welfare - New Insights

Chia-Chi Chen, Tseng-Ting Kao, Chung-Lun Lu and Shao-Wen Hung

1. Introduction

Animal welfare (AW) has been a significantly important issue in the world [1]. The idea of AW for the public usually comes from animal epidemic news or food scandals, and it has not been taken as an urgent issue to be solved in the world. Intensive farming has been considered as a sufficient way to operate in agriculture around the world because of the limited space. The government has been doing research projects on farm AW and encouraging researchers to conduct more research in this area.

AW is well organized in some countries such as Sweden and has been taken care of by the government and the responsible industries. Since these countries are the most advanced in the field of farm AW. Thus, how to improve the AW and solve the main AW problem in other countries according to the AW-concerned countries' approaches. At present, especially in the last years, the achievements made by scientists have been exceptional, leading to major advancements in the fast-growing field of animal science. Therefore, experimental animals play a very important role in scientific research [2].

Pigs, rodents, and aquaculture animals are important experimental animals. In order to obtain the accuracy of the experimental data and meet the basic quality requirements of biological experiment materials, the quality of the experimental animals for the biological experiments should reach the level of specific pathogen-free (SPF) [2]. These SPF animals are applied not only to meet the demand for biomedical research but also can be used to provide for research and development of drugs and vaccines. Furthermore, as AW has gradually attracted attention in recent years, the reduced animal pain and quantity and the increase of the experimental refinement are the important issues in the 3R (replacement, reduction, and refinement) of AW [3–5].

2. Animal welfare in various species

This book, "Animal Welfare: New Insights," is focused on new insights, novel developments, current challenges, latest discoveries, recent advances, and future perspectives in the field of AW.

2.1 AW in fungi and oomycetes: allies in eliminating environmental pathogens

The chapter provides information regarding the mechanism of action of these natural constituents and updates information on the species of fungi and oomycetes that have been studied so far. Thus, readers can have a base in this field and can further exploit what they have discovered to continue to improve the welfare of animals, addressing an ecological and healthy vision.

2.2 AW in overview of animal welfare aspects of Bali cattle with confined typology in Sumbawa regency, NTB, Indonesia

The chapter points out that the quality of life of cattle will affect their productivity, where productivity is an indicator of animal welfare. The recommendation is that there is a need for government policy intervention in the context of implementing animal welfare in Sumbawa as an effort to increase the productivity of Bali cattle.

2.3 AW in aiming to improve dairy cattle welfare by using precision technology to track lameness, mastitis, somatic cell count, and body condition score

The chapter aims to highlight the most recent advances in precision livestock farming (PLF) in this area. Finally, a discussion is presented on the possibility of integrating the information obtained by PLF into a welfare assessment framework.

2.4 AW in nerve injury model in rabbits: Benefits and pitfalls

The chapter outlines the risks and benefits of using this animal model in sciatic nerve injury studies. It also proposes treatment methods for common postoperative complications that can substantially reduce future study costs. To preserve ethical animal care standards in research, the recommended alternative models can be used instead of rabbits to study sciatic nerve injuries.

2.5 AW in human-wild animal conflict

The chapter deals with various human-animal conflicts and their mitigation strategies. Despite of these problems, conservation is likely to become increasingly utilized as biodiversity becomes increasingly threatened and methods of ameliorating threats lag behind.

2.6 AW in application of conservation and veterinary tools in the management of stray wildlife in Zambia

The chapter discusses animal migrations and some of the key reasons why they occur. Further, some conservation and veterinary measures are discussed that could be applied to address potential human conflicts with stray wildlife, which we believe are applicable to the Zambian situation.

2.7 AW in amphibian fauna of Manipur, north East India

The chapter shows that 27 different species of amphibian fauna reported from the region, along with conservation strategies and their importance, have been discussed.

2.8 AW in effect of agricultural pesticides and land use intensification on amphibian larval development

The chapter presents that the increase in human population had increased the demand for vital resources, including food, generating intensive and extractive exploitation and impacting natural ecosystems and biodiversity. These animals have special ecophysiological conditions because they have biphasic life cycles composed of an embryonic and larval aquatic development stage and the adult stage in humid terrestrial environments. For these reasons, amphibians have been observed with increased mortality rates, reduced prey availability, and affected growth rates.

2.9 AW in anti-arthritic activity of some *Boswellia* ssp. extracts in experimentally induced animals

The chapter explores that arthritis is a term often used to mean any disorder that affects joints. Rat-induced rheumatoid arthritis was applied in this study to study *Boswellia serrata*, which is a gum resin extracted from a tree. It appears to be a novel inhibitor of a pro-inflammatory enzyme and may possess other anti-inflammatory effects. Therefore, it is recommended to use *B. serrata* methanol extract to alleviate inflammation and oxidative stress caused by rheumatoid arthritis in rats.

3. Conclusion and future prospect

At present, AW has become a topic of very serious discussion worldwide. Humane breeding has become an issue that has been given international attention in recent years. However, many people are still very unfamiliar with this concept. The foundation of humane feeding is based on AW. The main appeal is to allow animals to have five freedoms. When animal feeding meets these conditions, it can be regarded as meeting the basic requirements of humane feeding. The basis for the sustainable implementation of humane breeding is actually consumers. If consumers do not support the concept of humane feeding and do not agree with the price difference that should be paid for the production of humane products, then producers have no resources to put humane concepts into the production process. Therefore, when consumers pay attention to humane production in terms of consumption behavior, then only more producers are willing to raise livestock and poultry in a humane way. As long as the insistence of both consumers and producers is satisfied, animals can be treated better.

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Section 2

Peripheral Nerve Injury

Chapter 2

Nerve Injury Model in Rabbits: Benefits and Pitfalls

Wesley P. Thayer and Sara C. Chaker

Abstract

Peripheral nerve injury is widely studied through the sciatic nerve injury model. Although many animal models are used for sciatic nerve injury studies, rabbits are reported as the third most commonly used animal model. However, there is a significant gap in the literature describing common postoperative complications following sciatic nerve injury in rabbits. This chapter analyzed postoperative complications recorded from an original study that tested 40 mm sciatic nerve gap repairs in 56 rabbits. Autophagy of the toes and pressure ulcer development on the injured limb were the two most common and severe postoperative complications seen. These impairments ultimately led to 23.2% of the rabbits requiring euthanasia prior to the study endpoint. This raised the cost of the study by over $25,000. This chapter outlines the risks and benefits of using this animal model in sciatic nerve injury studies. It also proposes treatment methods for common postoperative complications that can substantially reduce future study costs. To preserve ethical animal care standards in research, we recommend alternative models be used instead of rabbits to study sciatic nerve injuries. However, if rabbits must be used, we encourage using the treatment protocol outlined below.

Keywords: peripheral nerve injury, animal model, rabbit animal model, laboratory animal welfare, sciatic nerve injury, ethics and welfare

1. Introduction

Peripheral nerve injury is an exceedingly common injury that comprises nearly 2–3% of all patients admitted to a Level 1 trauma center [1, 2]. Despite this high incidence of patients with this injury, clinically accepted methods for treatment have yet to establish consistent success in restoring nerve function. It is reported that only 20–40% of direct nerve repairs achieve a high level of motor and sensory recovery [3]. In addition, the complex cellular and molecular pathology behind nerve recovery following injury provides an additional barrier to developing an effective treatment for traumatic peripheral neuropathies. Therefore, research endeavors have dedicated extensive efforts to developing treatment methods that address the pathophysiology of this injury to yield more remarkable functional recovery and tissue regeneration.

In pre-clinical research, animal models have massively expanded our knowledge of the biochemical mechanisms of diseases. In peripheral nerve injury research, *in-vitro* techniques are less commonly used due to their inability to mimic endogenous nerve regeneration complexities [4]. Conversely, *in-vivo* research has shown great translational potential for clinical treatments, making this method more common. The sciatic nerve injury model is often the model of choice for the exploration of this injury. The relatively large size of the sciatic nerve provides easy access for implementing and studying surgical interventions [4]. Although the sciatic nerve is the most common nerve for the study of peripheral nerve injury, there is a great deal of variance in the literature regarding the choice of animal model for experimentation.

Rats are often the animal model of choice for many researchers studying sciatic nerve injury [5–7]. In recent years, there has been a relative increase in nerve injury studies using rabbit models [8–13]. The use of rabbits in the sciatic nerve injury model has shown to be an excellent method due to their size, docility, ease of handling, and short life span [14–16]. However, their sensitivity to surgical implants, although beneficial when determining immunologic responses, may lead to greater costs than anticipated due to experiment-related complications. Additionally, the extensive maintenance required for the welfare of these animals can lead to higher experiment costs. Cages must be made from non-toxic materials so a rabbit would not be harmed if chewed or licked. It also must be designed so that a rabbit cannot hurt itself with sharp edges and be able to be maintained easily and repeatedly [17]. Pain in rabbits can also present difficulties in the use of this animal model. Rabbits do not display explicit behaviors when in pain, which without identification, can cause rabbits to die within 36 hours from distress from the pain [14]. Additional complications such as self-mutilation and the development of pressure ulcers can also result in the early termination of the experiment.

When conducting animal research, it is vital to adhere to the “Three Rs” principle, Replacement, Reduction, and Refinement. This framework allows proper adherence to maintain the welfare and minimize the distress of animals used in experimental studies. More specifically, replacement refers to using alternative methods in an area where animals would have been used, reduction refers to lessening the number of animals used in a study, and refinement refers to improving study protocols to minimize the amount of distress experienced by the animal. Given this universal standard for conducting proper animal research and the commonality of rabbit models for the study of peripheral nerve injury, it is essential to analyze the general benefits and drawbacks of the use of rabbits in these experiments. This chapter will provide data on the unforeseen complications and proposed interventions we have documented during an original experiment testing 40 mm sciatic nerve gap repairs in rabbits [18]. We hope this chapter provides greater information on this animal model to reduce pain in rabbits in future experiments and potentially persuade others to opt for an alternative animal model when studying nerve injury.

2. Sciatic nerve injury in rabbits

Although relatively common, the use of the rabbit model in sciatic nerve injury studies still presents many gaps in the literature outlining specific techniques for success. A recent study by Merolli et al. investigated the sciatic nerve gap-injury model in rabbits and provided greater detail for nerve-gap repairs in this animal model [19]. In the clinical setting, peripheral nerve injuries may require an artificial device called a “nerve conduit” placed over the nerve to aid in the regeneration of the nerve. These devices have been most commonly studied in the rat animal model for sciatic nerve injury. However, this model provides minimal translational potential due to the relatively small size of the rat sciatic nerve restricting the length of the devices being studied. In this case, the rabbit model can be instrumental given their relatively larger sciatic nerve and general ease of handling compared to other higher species animal models. Merolli et al. successfully introduced a novel method for transecting the nerve in a uniform and timely manner [19]. Despite the higher regulatory standards for the use of rabbits in experimental studies, the authors still believe that the higher translational potential of this animal model outweighs the higher standard of care.

The rabbit sciatic nerve injury model has also been implicated in investigating potential new therapies to promote nerve regeneration following injury. Li et al. evaluated the efficacy of nerve growth factor following a sciatic nerve crush injury in rabbits. They found that high-frequency ultrasound-guided injections of nerve growth factor led to more remarkable nerve recovery outcomes [20]. The size of the rabbit sciatic nerve and the greater translational potential of this larger animal compared to smaller animal models makes their results incredibly promising. The study of nuanced treatment methods for peripheral nerve injury is becoming increasingly common in the literature. Therefore, with more studies employing this animal model, it is pertinent to develop and provide a standardized protocol for the adequate care of rabbits used to study sciatic nerve injury.

2.1 Common operative technique

The sciatic nerve injury model was first developed by Wall et al. in an effort to study the behavioral effects caused by the complete transection of this nerve in animals [21]. The sciatic nerve is the largest nerve, therefore handling and repair are comparably easier than other nerves [22]. One of the most common lesions studied is axonotmesis, or compression of the nerve [4, 23]. Compression injuries utilize a crushing mechanism that leads to damage of the axons without disrupting the integrity of the epineurium. This method of injury leads to functional damage to the sciatic nerve without the need for surgical repair. Crush experimental models are mainly used to mimic and subsequently understand the biological mechanisms behind peripheral nerve injuries caused by mechanical compression.

The other common nerve lesion studied is neurotmesis, or complete transection of the nerve. This injury requires complete disruption of the axons and epineurium. Clinically, one-third of peripheral nerve injuries are caused by a laceration from a sharp object [24, 25]. Due to the nature of this injury, lacerations often lead to neurotmesis of a peripheral nerve. Therefore, *in-vivo* studies investigating transection nerve lesions are more prevalent in the literature for their high translational potential into clinical nerve repair methods.

In our original experiment, we measured different repair techniques following complete transection of the sciatic nerve in rabbits. The rabbits were sedated with a mixture of Ketamine (40 mg/kg) and Xylazine (9 mg/kg) given intramuscularly once on the non-experimental leg. Anesthesia was then maintained with Isoflurane 2% at 3 mL/minute. A 5 cm incision was made longitudinally parallel to the femur using standard sterile operating procedures. The left sciatic nerve was exposed through a split-muscle technique, and 40 mm of sciatic nerve graft was harvested. In our original experiment, rabbits were subject to one of three nerve injury cohorts, cut without repair, reverse autograft, and repair with a sterile nerve conduit. For the second cohort, the sciatic nerve was cut using sharp scissors, and the harvested nerve section was reversed 180° and reattached to the proximal nerve at both ends using a 9–0 nylon suture (Ethicon, Somerville, NJ). For the third cohort, the 40 mm deficit was repaired by suturing in a nerve conduit using 9–0 Ethicon sutures (Ethicon).

Once the specific nerve injury was completed, the muscle plane was closed by layers using a 3–0 Vicryl (Ethicon) interrupted suture pattern, and the skin was closed with a 5–0 Monocryl running suture pattern (Ethicon). This operative procedure was conducted in accordance with the Guide for Care and Use of Laboratory Animals and approved by our corresponding Institutional Animal Care and Use Committee (IACUC).

2.2 Postoperative care

Postoperative care is a critical step in maintaining the well-being of the animal and avoiding any potential complications. Despite multiple regulations and rules for the overall reduction of pain and suffering of laboratory animals, complications can be inevitable. Here we outline the specific steps we took following the surgical procedures to minimize distress in the rabbits.

Immediately following surgery, rabbits were monitored by study personnel until they fully recovered and were able to be transported back to our animal facility per our IACUC protocol. For pain management, every 8 hours for the first 24 hours, 0.02–0.05 mg/kg of buprenorphine hydrochloride was administered subcutaneously or intramuscularly. After the initial 24 hours subsided, 0.1–0.3 mg/kg/24 hours of meloxicam was given as needed for 72 hours. Pain assessments were made using the rabbit grimace scale [26]. This scale evaluates facial actions such as orbital tightening, cheek flattening, nose shape, whisker position, and ear position. This scale has shown to be a reliable method for assessing pain in rabbits.

Rabbits were individually housed in Allentown rabbit cage rack systems, and a non-contact Techboard was placed underneath the racks for urine and excrement collection. Cages were changed every 2 weeks. Rabbits were fed through an automatic feeder and had free access to food and water 24 hours a day. A high-fiber diet and water were replaced every day. Additionally, the room in the animal facility that held the rabbits was set to a 12-hour light/dark cycle. Rabbits were monitored weekly by study personnel and daily by animal care staff. During the weekly inspections, any complications were recorded, and rabbits were weighed. At the end of the specified postoperative period (3, 6, or 12 weeks), the rabbits were euthanized by intravenous injection of 125 mg/kg sodium pentobarbital. For the purpose of the original study, the nerves were then harvested for either immunohistochemistry or magnetic resonance imaging [18].

3. Postoperative complications and proposed solutions

3.1 Autophagia

Injury to the sciatic nerve causes muscle weakness in the affected limb and decreased sensation [4]. This often leads to complications experienced across multiple animal models. Autophagia is often reported among these complications. Initial theories believed self-mutilation was due to the animal's inability to sense the injured limb and consequently attack it as if it was a foreign body [23]. However, the histology behind peripheral nerve injury and known mechanisms following nerve injury support the theory that the onset of this phenomenon is linked to the axonal regeneration and subsequent generation of abnormal sensations from the injured nerve [23, 27].

In our original study, self-mutilation occurred in about 36% of the rabbits. The affected rabbits mainly chewed on the digits of the affected limb, however, there was additional chewing to the surgical site and the dorsal and web spaces of the injured foot. Our solution to this complication was to place a plastic Elizabethan collar with soft edges on the rabbits in the hope that it would deter autophagia. After this intervention's implementation, the autophagia incidence dropped by nearly 10% in the affected rabbits ($p = 0.0093$). In addition, euthanasia related to self-mutilation decreased from 7.5 to 1.04% ($p = 0.00164$).

Initially, when autophagia was sighted, the rabbits were placed in donut collars (**Figure 1**). These collars were initially chosen due to their softness, lack of toxicity, and ease of application and cleaning. However, this type of collar did not prevent the rabbits from reaching their hind limb. Therefore, we were required to use plastic Elizabethan collars with soft edges. We found that due to the greater range around the rabbit's head, these collars were more successful at preventing the rabbits from reaching and subsequently harming the toes on the injured limb. In addition, the relatively inexpensive cost of these types of collars proved to be incredibly advantageous. We purchased two sets of 10 collars, which made the treatment of autophagy expedited. It also allowed for an immediate exchange of soiled collars for clean ones.

A critical aspect of this treatment to note if used is that often our study personnel would find the collars covered in waste. Therefore, to maintain sanitary conditions and prevent eye infections in the rabbits, the collars had to be changed regularly and checked daily. Additionally, with these collars, if moisture collects where it is attached to the neck of the animal, fungal rashes can occur. Thus, it is also essential to check the necks of the rabbits to ensure there is no excessive moisture. Lastly, we found that the rabbits would often chew at the rims of the collars, so we had to provide non-toxic coverings, such as hypoallergenic surgical tape, to replace the soft sides of the collar. Despite these minor issues, this simple solution was shown to be successful in reducing this complication in our rabbit model.

Figure 1.
Example of an Elizabethan collar (left) and a Donut collar (right) used as a treatment for autophagy in original study.

3.2 Pressure ulcers

An additional complication we encountered was pressure ulcers on the plantar aspect of the injured foot. Pressure ulcers can cause excruciating pain and adequate steps must be taken to prevent the development of this ailment in the animals. Ulcers, specifically on animals' heels, are incredibly common in sciatic nerve injury models. Rabbits are often more prone to this type of injury due to the overall lack of sub-dermal padding in the heel of their hind limbs [28]. Additionally, following nerve injury, dysesthesia can occur in the injured limb leading to dragging of the foot, ultimately contributing to the overall poor condition of the injured foot [29].

In our original study, we reported that about 23% of the rabbits developed pressure ulcers. This was the second most frequent postoperative complication experienced. These ulcers often developed into severe morbidities where the base of the ulcer reached the calcaneus. To prevent and lessen animal suffering, we developed an "ulcer cushion" and utilized this device to treat the ulcers. Our "ulcer cushion" consisted of a

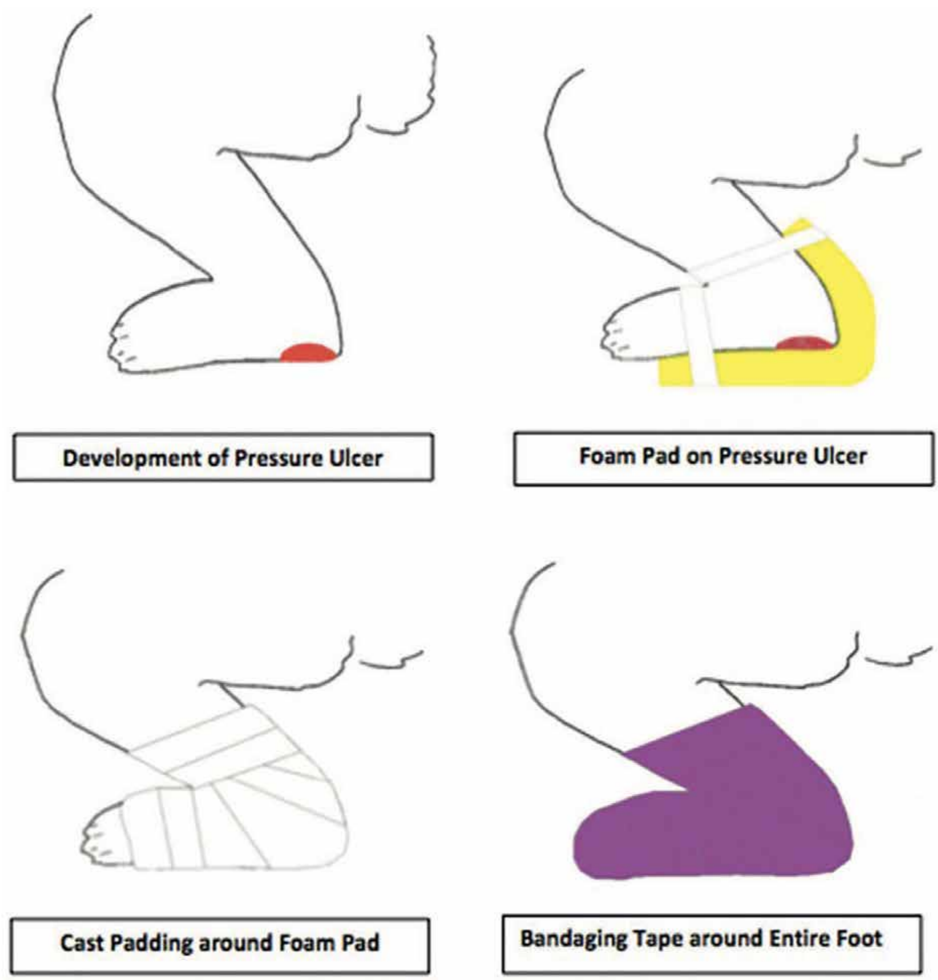

Figure 2.
Illustration of our developed "ulcer cushion" utilized in our original experiment to treat and prevent severe pressure ulcers.

foam sheet custom-fitted to the bottom of the rabbits' foot (**Figure 2**). Two personnel were used to apply the cushion, one to safely hold the rabbit and another to place the foam onto the affected foot. After the foam was placed onto the foot, it was wrapped in cast padding, and the entire foot was wrapped in veterinary bandaging. When the bandaging was placed onto the foot, appropriate pressure was applied so the cushion would stay in place but not affect the circulation of the foot.

This treatment method was based on the clinical standard for treating this condition in humans. Unfortunately, there is yet to be a commercially made device to treat this ailment in animals, which led to the development of our own manufactured device. We believe this method eased pressure from the foot and even acted as a disease prevention mechanism for autophagia. Additionally, besides routine changing of the bandages, there were no other issues found with this treatment compared to the collars mentioned previously. Therefore, applying this cushion to the injured foot following sciatic nerve injury in rabbits is strongly recommended as a preventative tool for pressure ulcers.

4. Cost analysis

Compared to larger animal models, rabbits are a cost-effective option for sciatic nerve injury experimentation [4]. Yet, rabbits can often experience many complications that ultimately lead to increased costs. When the animal experiences complications beyond remedy, euthanasia must occur, and additional rabbits and their corresponding supplies will have to be ordered to replace the lost animals. This goes against the principle of reduction, a pillar in the universal framework to promote humane animal research. Our treatment methods outlined above completely subsided the need and cost for additional rabbits. In our original study, the total cost for the purchase and care of the rabbits required to complete the experiment should have been around $108,000. The added cost of acquiring additional rabbits to replace the ones that were lost was $25,414.94. Therefore, complications alone increased the cost of the study by 23.54%.

The cost of our interventions proved to be substantially inexpensive. When the cost of all the materials used for the treatment of the autophagy and pressure ulcers were summed, our treatments were around 66 times less expensive than ordering more rabbits ($376.95 vs. $25,038.44). These intervention methods proved to have the ability to reduce the number of animals required for the completion of the study, which can save thousands of dollars in experimental costs.

5. Discussion

The use of rabbits for sciatic nerve injury models can provide greater acuity for the investigation of peripheral nerve injury repair methods compared to smaller rodent animal models. In addition, their ease of handling and biocompatibility make rabbits an excellent choice for nerve injury experimentation. Although this model is less costly than larger animal models, rabbits can experience many complications that can almost negate this difference. In our original experiment, where we utilized rabbits to test sciatic nerve repairs, we recorded all postoperative complications experienced by the subjects. We found autophagy and ulcers of the heel to be the most common complications experienced by the rabbits. In this chapter, we outline how we treated and managed these complications in the hope that future studies can use these techniques to prevent these morbidities from occurring.

Autophagia or self-mutilation of the toes of the injured limb is a common complication across multiple animal models. With sciatic nerve injury, dysesthesia is common and is suspected to be the cause of this response in rabbits [22]. Amputation or euthanasia before the intended study endpoint is often required when this complication becomes severe. However, these solutions lead to greater distress for the rabbit and increased costs. Our proposed solution for this complication includes placing an Elizabethan collar on the rabbit, making it more challenging to bother the injured limb. With this inexpensive and simple method, we were able to reduce the number of animals with autophagia by nearly 10% and reduce the number of animals requiring euthanasia due to severe self-mutilation by 6%.

The second most common complication we encountered was the development of ulcers on the heel of the injured foot. Currently, there is no standard method to treat this complication in animal models. These ulcers can become extremely severe if left untreated, often developing so deep into the foot that the bone of the heel can be visible. Therefore, to maintain the well-being of the rabbits, it is vital to develop a standardized method of care when this morbidity occurs. Our solution was the development of an "ulcer cushion." This essentially was a custom-fitted piece of foam placed under the injured foot and then secured with cast padding and veterinary tape. Although we did not perform a statistical analysis on the effectiveness of this method, we believe this solution alleviated the pressure placed on the injured foot and even worked indirectly to prevent autophagia.

These developed treatments drastically decreased the overall cost of the experiment as well. The price of replacing rabbits that had to be euthanized prior to the intended study endpoint can lead to substantial unbudgeted costs for the experiment. In our original study, the price for additional rabbits and the subsequent housing and care required, led to an additional cost of $25,414.94. This raised the cost of the entire experiment by nearly 24%. However, our proposed treatments dramatically reduce this cost to merely $377. Therefore, these developed treatment methods can save thousands of dollars, increase the welfare of the animals, and lessen the number of animals needed to complete the experiment.

One aspect of both treatments to note is that they require high levels of maintenance. The collars had to be changed often to maintain sanitation and avoid bacterial infections. Study personnel often returned to see the collars covered in feces. Additionally, moisture can be easily trapped around the neck of the rabbit where the collar is placed, leading to a high risk of developing fungal dermatitis. Similarly, the ulcer cushions had to be replaced and monitored often throughout the study. Another aspect future researchers should consider if utilizing these proposed treatments is how behavioral assessments may be affected. Moreso, with the placement of the cushion on the injured foot, the rabbit's mobility will be disturbed and subsequently interfere with any walking assessments. Ambulatory assessments are the most used postoperative measurements in nerve repair studies [30–33]. Therefore, with a cumbersome cast placed on the rabbit's foot, one can anticipate the animal to drag their foot and even have an exaggerated movement of the protected foot when raising it, compared to the unaffected limb. These details should be strongly considered when implementing these treatments in an experiment that requires postoperative behavioral assessments. However, if these additional features of the treatments cannot be handled accordingly, we encourage using alternative animal models that allow for large sciatic nerve injury modeling but may not be as sensitive as the rabbit model.

6. Conclusions

In this chapter, we have outlined our experience working with rabbits to study repair methods for sciatic nerve injury. This animal model can provide great benefits for pre-clinical experimentation of peripheral nerve injuries. However, rabbits tend to have greater sensitivity to this particular impairment. With the lack of literature outlining common post-operative complications experienced in this animal model, it was imperative to discuss our findings and potential solutions for future research. Therefore, if an experiment cannot meet the suggested treatment protocols for maintaining the animals' well-being, we suggest opting for an alternative, more resilient model for studying sciatic nerve injury. If a rabbit animal model must be used, applying the treatment methods outlined in this chapter immediately postoperatively can drastically reduce the amount of animal suffering and allow the experiment to progress successfully.

Conflict of interest

The authors declare no conflict of interest.

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Section 3

Pesticides

Chapter 3

Effect of Agricultural Pesticides and Land Use Intensification on Amphibian Larval Development

Claudia Patricia Camacho-Rozo
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Abstract

The increase in human population had to increase the demand for vital resources, including food, generating intensive and extractive exploitation, and impacting natural ecosystems and biodiversity. Land degradation of ecosystems is a serious and widespread problem in the world. The expansion of the agricultural frontier is by direct or indirect human-induced processes, expressed as long-term reduction or loss of biodiversity. The expansion and industrialization of agriculture had been negatively affected by soil fertility, the climate, biogeochemical cycles, bodies of water, and loss of biodiversity on different spatiotemporal scales. Intensive agriculture, in the form of monocultures, is subjected to strict pest controls for the use of highly toxic agrochemicals. Pesticides are used in monocultures by spraying aqueous dilutions. Knowing the toxic effect of pesticides and agrochemicals on amphibians is very important. These animals have special ecophysiological conditions because they have biphasic life cycles composed of an embryonic and larval aquatic development stage and the adult stage in humid terrestrial environments. For these reasons, the amphibians have been observed with increased mortality rates, reduced prey availability, and affected growth rates.

Keywords: agriculture, growth, human land use, malformation, pesticides use, sublethal effects, survival

1. Introduction

Ecosystem transformation may be an inevitable outcome of the combined impacts of multiple drivers [1–3], including the increase in the human population, their activities, and the demand for resources [4, 5]. The conversion of natural habitat to other land covers through changes in human land use is a principal cause of deforestation, the loss of biodiversity, and local/global extinction of species in natural terrestrial ecosystems [1, 3, 6]. In the world, ecosystem transformation is associated with the rise of agricultural systems, these new ecosystems increase human appropriation of the Earth's net primary production, reducing the amount of energy available for all other species, and influencing a range of ecosystem processes and services [3, 4, 7].

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To provide for human needs, over 50% of the global usable land is already for pastoral or intensive agricultural uses [3, 5]. The increase in the agricultural frontier and overexploitation lead to the use of a high number of chemical products that affect both the communities present in bodies of water and the soil [8–10]. Among the communities most affected by these agents are amphibians, which have limited spatial mobility [11–13], physiological and ecological specificities, that restrict their distribution and habitat use [14–16].

Amphibians present a biphasic life cycle in their development, an aquatic larval stage, adapted for rapid growth, and a terrestrial adapted for dispersal and reproduction [17–19]. The aquatic environment is the first habitat faced by anurans with complex life cycles [16, 18], because different restrictions imposed by the environmental gradient may be present during larval development [16, 17].

In the terrestrial environment, adult anurans select and colonize different habitats for oviposition and development of their young [20–22]. Tadpole uses different microhabitats, such as semi-permanent pools, permanent pools, temporary pools, phytotelmata seasonal and permanent streams or rivers, and under leaf litter [16, 18]. These bodies of water can be mesotrophic or oligotrophic, and present different biotic and abiotic characteristics, which could affect their adaptation [20, 23].

The larval stages of anurans in disturbed environments and recovery processes are crucial for the persistence of the species in a specific locality [20, 24, 25]. Their survival depends directly or indirectly on the requirements of these organisms for conditioning and the presence of suitable microhabitats for the species throughout their life cycle [24, 26, 27].

Environmental and spatial processes present in anuran assemblages with complex life cycles respond differently within water bodies [22]. These organisms play an important role in aquatic ecosystems, especially in the absence of higher trophic levels [28]. These organisms present different traits in the oral disc and diets that allow them to occupy more functional space. The tadpole's filter-feeding can change the composition and abundance of algal species, thus affecting the amount of chlorophyll and primary productivity [25, 28]. Scraper larvae can affect other primary consumers as epiphytes, present on the bottoms of water bodies. The changes in the structure and function of freshwater ecosystems provide insight into the mechanisms of interaction between anuran assemblages and their relationship with the ecosystem [25, 28]. However, numerous environmental variables can directly or indirectly affect anuran larval growth, survival, and mortality rates [20, 29, 30]. Tadpoles can inhabit water bodies that present a gradient of permanence over time [20]. For the tadpoles, the opportunity to remain longer in a water body would imply increasing size and decreasing the probability of mortality during metamorphosis [19, 31]. The larger size would be related to an earlier onset of reproductive maturity, which is advantageous in terms of egg production and sexual attraction, among other variables [21, 31, 32].

Agrosystems use fertilizers and pesticides, these affect the amphibians populations of the terrestrial and aquatic ecosystem. Pesticides affect amphibian populations with lethal, as well as sublethal effects. The sublethal effects occur in the medium and long, decreasing the availability of prey for amphibians, which together with ecological and physiological stressors could restrict the transmission of matter and energy and growth rates [33, 34]. We reviewed the literature on dermal pesticide absorption and toxicity studies for aquatic life stages of amphibians.

2. Transformation of the territory and its impact on biodiversity

The transformation of ecosystems and ecological processes in the world is associated with the establishment and needs of human populations and their socio-cultural processes [5, 35]. The demographic increase has been progressive in the world. Humans have transformed between 40–50% of the natural ecosystems of savannas, forests, and wetlands into agricultural and urban systems [5, 36]. Over 50% of the global usable land is already in pastoral or intensive agricultural uses and urban systems, reducing the potential for the sustainable provision of many goods and services from natural ecosystems. These new systems have been causing negative effects on climate, soil fertility, biogeochemical cycles, land use, and diversity at different spatial scales [5, 37, 38].

Currently, more than half of the world's population lives in cities, occupying 3% of the earth's surface [3, 35, 39]. Humans appropriate one-third of the net primary productivity of the land and 8% of the ocean to meet their food, energy, and production and consumption needs for goods and services [39, 40]. Natural terrestrial ecosystems are a major source of timber, fuels, fuelwood, resins, and fibers, which provide provisioning services for humans [2, 3]. However, their extension and coverage have been replaced by new crop areas (12%) and pastures for livestock (25%) to produce the necessary food for a constantly increasing population; being the main drivers of the transformation of the structure and functionality of the landscape at different spatial and temporal scales [1, 5, 37]. The intensification of agricultural systems transforms natural terrestrial ecosystems by changing land cover and land use, resulting in deforestation, defaunation, and land-use change [1, 5, 9, 36].

Forest clearing processes have been permanent and at different intensities around the world, configuring different patterns of land use and, therefore, different deforestation dynamics [5, 41]. In the case of tropical rainforests, deforestation has increased, giving way to agricultural, mining, and silvopastoral uses [5, 36]. These changes in the landscape present differences in cover types, being heterogeneous matrices where the radiation balance and temperature have extreme fluctuations day and night [42, 43]. The matrices are characterized by having greater exposure and change in abiotic variables, such as wind intensity and frequency, temperature, solar radiation, relative humidity, greater water flow, and high water or saline erosion of soils [5, 36, 43]. In this sense, depending on the use, anthropogenic systems affect the quality and quantity of habitat for both vegetation and fauna found on the edges of the remaining forest fragments [1, 5, 44].

These matrices are surrounded by small fragmented patches of forest, which have different soil types and vegetation, and vary in size, shape, and isolation [45, 46]. The biological and physical interaction of these two transition zones generates an effect of changing environmental and biotic conditions at the edges [45, 47]. Thus, the edge effect is mostly associated with fragmentation and habitat loss [6, 46]. As habitat fragments, the geographic extent of the anthropogenic matrix increases, and the edge effect on remnant native forests increases, which increases their isolation as habitat loss is accentuated [20, 48]. As landscapes are transformed, the original continuity of native cover is broken, decreasing the reproductive success of native species and the genetic exchange between populations [1, 7, 49].

Fragmentation in tropical ecosystems directly affects population densities and the number of species, especially endemic species [50, 51]. Likewise, the edge effect and fragmentation generate an alteration of the habitat of native species [1, 7, 49] and favor the appearance of new exotic/invasive or disturbance-adapted species that compete with the rest of the species for resources [50, 52]. Habitat degradation and loss caused by ecosystem transformation processes [44, 52] result in the extinction of species of the taxonomic groups most sensitive to disturbance, such as amphibians and some reptiles [49, 52].

In 2000, it was considered that approximately 60% of the world's tropical forests were degraded due to anthropogenic disturbances [2]. Worldwide 70% of native forests are located less than 1000 m from a productive system [53]. In the productive system the activities, such as burning, spraying, logging, unmanaged soil fertilization, use of pesticides, and herbicides, are traditionally carried out [5]. These activities generate strong impacts not only locally, but also lead to ecological footprints on a regional scale. Elements, such as the edge effect, alterations in the composition of biota, presence of water bodies, and soil permeability, negatively affect biodiversity and ecosystem services [37, 54].

3. Response of amphibian assemblages to ecosystem transformation

Amphibians are essential components of many natural ecosystems. They are indicators of ecosystem health [55] and have important roles in natural food webs [56]. These animals are sensitive to environmental changes and require moist habitats with relatively low and constant temperatures [55]. In addition, the distribution of amphibians in forests may be determined by the heterogeneity of ground cover [57, 58] and the availability of microhabitats [56, 59]. The stages of larval of anurans (eggs, embryology, and tadpoles) are subject to different biotic and abiotic conditions that affect survival, development, and size during development [31, 60, 61]. Many anuran larvae exhibit phenotypic, physiological, and ethological adaptations in response to changes in the environment that will directly influence premetamorphic growth and development, developmental speed, growth rates, body size, weight at the end of metamorphosis and the length of the larval cycle [17, 62, 63].

The choice of the aquatic environment, by adult amphibians for oviposition, influences the rates of fertilization, embryonic development, larval growth, survival, and mortality of these organisms (**Figure 1**) [64–66]. Likewise, the structural and physiognomic characteristics of the aquatic habitat are determined by: 1) the temperature of the medium, 2) the amount of food available, 3) the amount of radiant energy through sunlight, 4) the amount of oxygen available, 5) the amount of accumulated excreted waste, 6) bacterial growth, 7) predation, 8) the space available per organism (density), 9) presence of growth-inhibiting substances and 10) variation in habitat size [16, 67]. In anurans, changes in environmental selective pressures accompany and determine development, body size, weight, and the timing of metamorphosis [18, 68], affecting the distribution of species and their use of different habitats [66].

The amphibian's different life-history stages may occur in disjunct habitats and function at different spatiotemporal scales (**Figure 1**) [22, 23, 69, 70]. Changes in the physical and biotic environment primarily affect physiological, ecological, and biological processes [18].

The interactions of these factors in anuran larvae (**Figure 1**) depend on the characteristics of the habitats selected. The parents select the site to lay eggs, as well as the characteristics of the microhabitats they use as a mechanism to mitigate competition and predation, due to different relationships over time [18, 70]. Tadpole survival, growth, and development are secondarily affected by the behavior of each species in predator-prey relationships and their phenotypic plasticity (**Figure 1**) [18, 70].

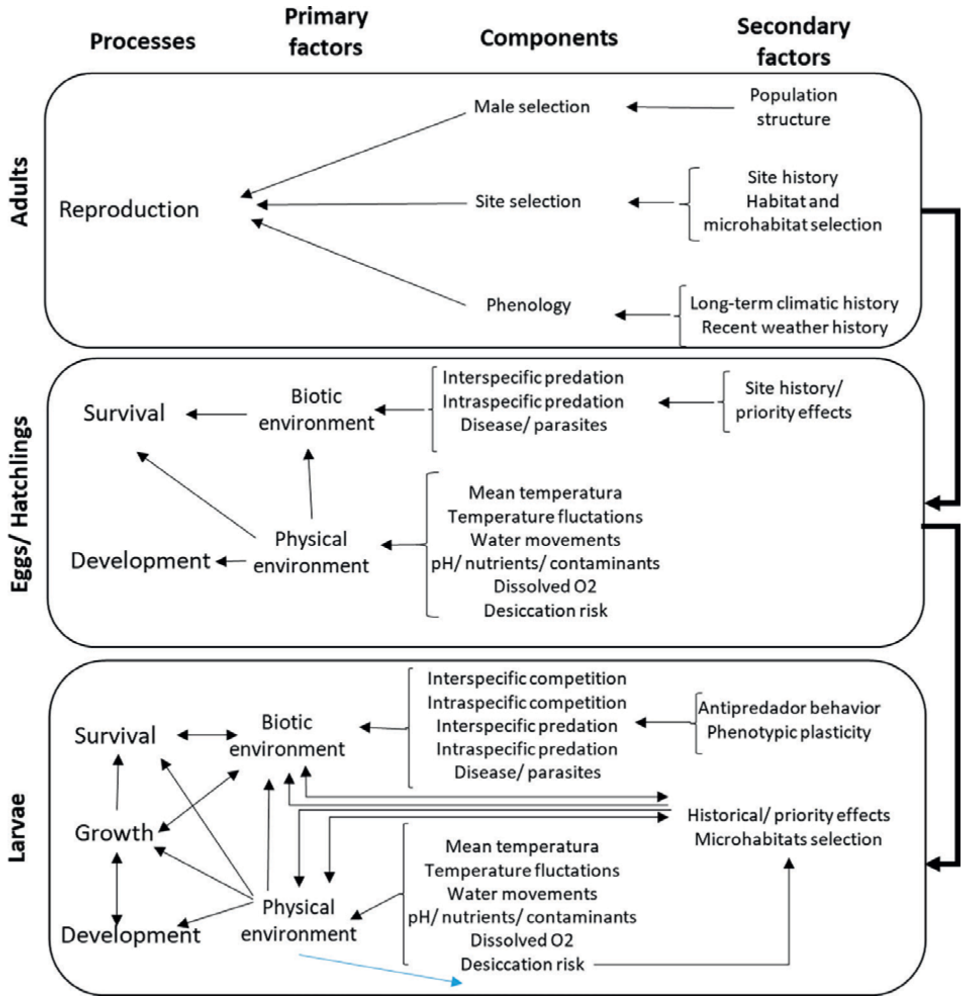

Figure 1.
Summary of factors affecting the biology and ecology of the anurans (adults, eggs, hatchlings, and tadpoles). These processes are influenced by primary factors in or of the biotic environment. The secondary factors are reflected in the reproductive ecology and behavior of adults; they can affect the biotic environment of a larva (microhabitat selection). The arrows indicate interactions and their directions, which need not be directly causal. Data from [18].

Biotic factors include but are not limited to food availability and quantity, population density (crowding), and predation [62]. Abiotic factors, such as environment, ambient temperature, photoperiod, and water body (water level, quality) directly influence amphibian larvae and physiological mechanisms related to growth and differentiation [62, 71–73]. The anthropogenic transformation of the landscape tends to be heterogeneous, thus imposing new adaptation challenges to amphibians, presenting in some cases high biodiversity and only those species that have greater phenotypic plasticity to abiotic variations and ecosystem disturbance can adapt [16, 17]. However, the patchy distribution of aquatic habitats together with the reduced dispersal capacity of some amphibian species could impede the colonization of new habitats by adults, so the selection of breeding sites could determine the occurrence of tadpoles in each habitat [22]. In the water body, tadpoles may select occurrence sites according to microhabitat characteristics based on food availability and predation risk [16, 22].

Intensification of agricultural practices is observed on a global scale, generating habitat loss, reduced landscape heterogeneity, and connectivity [10, 12, 74]. Amphibians depend on the quality of aquatic habitats for reproduction and development, as well as the surrounding landscape for the terrestrial phase [34]. In agrosystems the composition and abundance of amphibian species are low. Presenting generalist species that have different traits that allow these organisms to survive. Amphibians that lay their eggs in lentic water bodies and whose larvae develop there (without parental care) tend to be more tolerant to the anthropogenic transformation of the landscape [20, 75]. An example of this is foam nests which can be a successful strategy to colonize highly dynamic and ephemeral anthropogenic bodies [20].

4. Effect of pesticides on the development and growth of amphibian larvae

In the world, with the expansion of the agricultural frontier, the use of fertilizers and pesticides has become widespread, with negative effects on amphibian populations [76], and the use of herbicides and pesticides contaminate the air, soil, surface water, and subsoil, generating serious problems for community dynamics and biodiversity [76–78]. Chemical pesticides have been one of the main resources used in intensive and conventional agrosystems for the control of some pathogenic fungi, insect pests, and weeds [7, 77]. The chemical composition of pesticides varies according to the degree of toxicity and persistence associated with their origin (natural and synthetic). Natural pesticides originate from pyrethrin, nicotine, and rotenone [7, 79].

Synthetic pesticides have hydrocarbons, chlorinated pesticides, organophosphates, and carbamates as their groups of origin. However, cyclodienes, carbamates, and organophosphates were eliminated from 50% of the world commercial market [77, 79], due to their high toxicity and collateral effects on other nontarget species [77]. In wild populations (amphibians, reptiles, birds, and mammals) [79], some effects are caused by residues of organic insecticides and organophosphates, which are abundant in the environment, are known [77, 79].

Pesticides in amphibians, not only reduce prey availability, but also reduce the transmission of matter and energy and, ultimately, growth rates [20, 34]. Within agroecosystems malformations in adult anurans and tadpoles are very common, being one of the main causes of high amphibian mortality rates [34, 80].

Among the different adverse effects of organophosphates on anurans are changes in survival and growth rates, morphological malformations, and some behavioral problems [33]. Organophosphate pesticides, such as endosulfan, are highly toxic in the environment [77, 79] and degrade slowly, leading to accumulations in food chains [79]. The impact of endosulfan on wildlife is associated with lethal effects on some fish and on the larval stage of amphibians present in water bodies near the areas where the pesticide is applied. Among the nonlethal effects, there are delays in the growth and development rates of amphibian larvae [31, 81].

Chlorpyrifos remains in the water for only a few days or weeks [33]. The tadpoles to high concentrations of chlorpyrifos have significant negative effects on growth and metamorphosis development time. On the other hand, the use of pyrethroids are pest controllers due to their low toxicity in birds and mammals, nevertheless showing that they are highly toxic to aquatic organisms [82]. The tadpoles both lethal and sublethal effects have been recorded, which are associated with behavioral changes, affecting larval cohorts and gregarious behavior patterns that favor the search for food and cause greater predation in intoxicated larvae [78, 82].

Among the pyrethroids is cypermethrin (Cy), which is highly active and effective against a wide range of pests that affect agriculture, public health, and domestic animals [33, 78], but it also reduces the biodiversity of aquatic organisms, such as crustaceans, aquatic insects, fish, and anuran larvae, which are not part of the target species for control [78, 82]. The cypermethrin in amphibian larvae causes the death of nerve cells in anurans, and have also been determined that, when exposed to this pesticide during the early stages, developmental inhibitions are observed [78]. However, the different concentrations of cipermectrin that produce mortality and those required to produce malformations are different.

Pesticides are a group of substances with varying degrees of toxicity and very diverse characteristics, among which two large groups can be distinguished: (1) elements that are defined by the type of use of the pesticide, according to the organism on which they act, such as insecticides, herbicides, acaricides, fungicides, and rodenticides. (2) according to the chemical structure of the substances with pesticidal activity, which are divided into organophosphates, organochlorines, carbamates, carboxylic acids, pyrethroids, amides, anilines, alkyl derivatives of urea, heterocyclic compounds with nitrogen, phenols, imides, inorganic compounds [77].

Sediment entrainment by drainage and irrigation systems could generate eutrophication processes in aquatic systems and greenhouse gas emanations [83]. Contamination of water sources has negative effects on populations, for example, the amphibians do not have shelled eggs and their skin is a permeable organ. These animals are more sensitive to pollution and deterioration of the environment [33, 78, 82]. Tadpoles could be directly or indirectly in agricultural areas, being exposed to contaminants present in both their aquatic and terrestrial habitats [20, 84, 85]. The sublethal effects of cypermethrin are abnormalities, changes in behavior, the acceleration or delay of metamorphosis due to chemical stress, loss of appetite, mutations, death of amphibian nerve cells, low rates of the embryo, and tadpole development [78, 82] and lethal effects (high mortality rates).

The incidence of agrochemical ecotoxicity in anuran larvae has shown different responses about the species, the concentration of the contaminant, its degradation rate, exposure times, and to predator pressures [86]. Some studies have shown that in crops, the use of agricultural inputs at different concentrations is often not high enough to cause immediate mortality but generates sublethal consequences, such as depressions in the immune system of amphibians, which makes them more susceptible to parasites and malformations in their morphology [33, 78, 82] or the decline of the different species and populations of the impacted habitat, where alterations in the food chain may have greater consequences than direct chemical effects [86].

5. Case study

Under experimental conditions, we evaluated the effects of the biocide cypermethrin (Cy: the substance of the pyrethroid chemical group), the active compound of the commercial product ®Fuminate in 80 larvae of Mannophryne vulcano, at larval development stages 25 and 26 according to Gosner's table [87]. Three treatments with ®Fuminate and control were designed, each with 20 replicates.

In the experimental subjects exposed to different concentrations of cypermethrin and the control, the following variables were studied: (1) stage according to Gosner [87];

(2) body weight (g), and (3) total length (TL). Follow-up of the test for each treatment and larva was carried out until the completion of the metamorphosis process, observing the sublethal effects on its development.

In each of the experiments, the following records were obtained: with treatment level 1) in concentrations of one (1) ml of cypermethrin, diluted in one (1) liter of water (concentration suggested by the manufacturer for the bathing of cattle, horses, and domestic dogs) obtained 100% mortality in less than 12 h. The high degree of toxicity of this pyrethroid to aquatic life organisms is demonstrated, especially to anuran larvae, which cause lethal and sublethal effects [78, 82]. In the treatments of cypermethrin, level 2) at 0.4125 ml/l, level 3) at 0.206 ml/l, and the control treatment (no insecticide), no deaths were recorded during the first 24 h.

The variables studied indicate that *Mannophryne volcano* tadpoles exposed to sublethal concentrations of cypermethrin were affected in the rate of weight gain (**Figure 2**), weight (**Figure 3**), and growth (**Figure 4**), until the end of the metamorphosis. However, no increase in length during the larval period or malformations were observed as suggested by Carr et al. [88] for similar cases. This could be related to the time of exposure to the xenobiotic substance and the embryonic stage in which the organisms were found, being more likely to observe these effects in organisms exposed since the laying of eggs by the female.

Tadpole growth and weight gain showed similar behavior in the three levels evaluated. In the larvae of *M. vulcano* there were no significant differences between the different levels in both development and growth, which indicates that the first and final stages are the most critical in larval development [33].

Survival in the two treatments with cypermethrin concentrations registered the lowest values. The highest pesticide concentration had the lowest survival of metamorphs compared to those recorded for the other levels. It is important to keep in mind that tadpoles are more susceptible to contaminants when they are in the transition from an aquatic to a terrestrial phase, where sublethal effects could be greater during this critical phase.

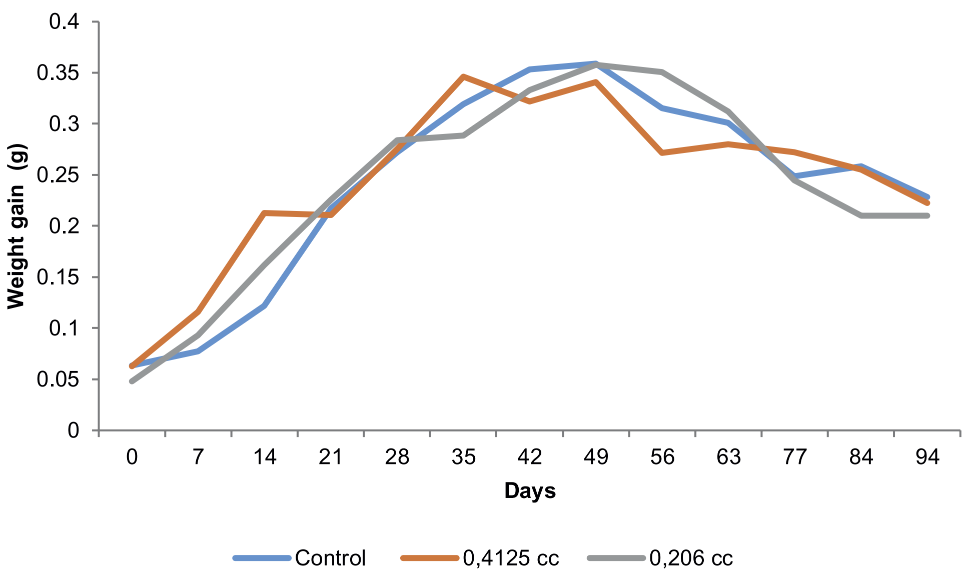

Figure 2.
Weight gain of Mannophryne vulcano larvae from the average values, during the evaluation of the three treatments.

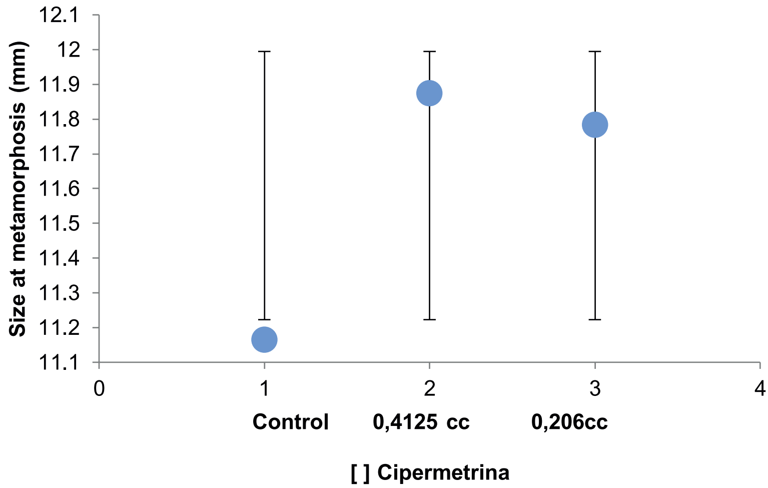

Figure 3.
Average size at the end of the metamorphosis of Mannophryne vulcano, during the experiment with three types of pesticides.

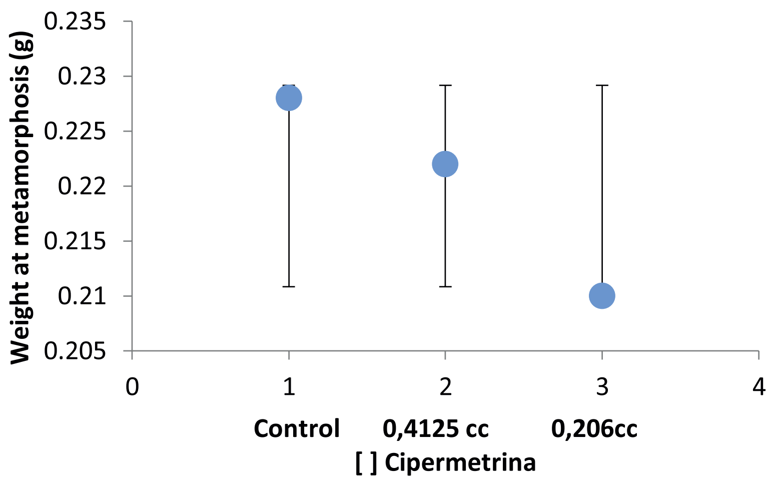

Figure 4.
Average weight at the end of the metamorphosis of Mannophryne vulcano, during the experiment with three types of pesticides.

It is also important to highlight that the growth, development, and timing of the larval period depend on environmental factors, such as temperature, quality, quantity of food, and density, which were previously evaluated. According to Izaguirre et al. [78] larvae from temporary water bodies tend to be more sensitive to cypermethrin concentrations compared to larvae from lotic habitats.

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Competing interests

We declare that we have no competing interests.

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Section 4

Wild Animal

Chapter 4

Human–Wild Animal Conflict

Yogeshpriya Somu and Selvaraj Palanisamy

Abstract

Wildlife species have faced the impacts of human dominion over the world throughout history. More recently, there has been increased global protection for endangered species as a result of greater awareness and concern for biodiversity. Conservationists are becoming increasingly concerned about the pervasive issue of conflicts between human and wildlife interests, especially as it relates to large carnivores that have the potential to harm both cattle and people. Pre-conflict mitigation refers to proactive measures like fences while post-conflict mitigation refers to compensation payments for lost animals. Both can be used to lessen conflicts between wild animals and livestock owners. The goal of compensation programs is to raise people's understanding of wildlife. But compensation programs are frequently criticized for being insufficient, difficult, and expensive. Compensation programs must be part of a comprehensive approach that includes options for controlling offending animals, proactive mitigation measures, and, in some cases, broader financial incentives for changes in land use practices in order to be more effective. The latter method has been used in India and several African countries. This chapter deals with various human-animal conflicts and their mitigation strategies. Despite these problems, conservation is likely to become increasingly utilized as biodiversity becomes increasingly threatened and methods of ameliorating threats lag behind.

Keywords: wild animals, human crop, mitigation, compensation

1. Introduction

Human–wildlife conflict (HWC) refers to the negative interactions between humans and wild animals, with undesirable consequences both for people and their resources, on the one hand, and wildlife and their habitats on the other [1]. As scientists learn more about biodiversity, more species are listed as endangered, more processes are identified as threats to biodiversity, and there is less agreement on the significance of each threatening process. As these pressures intensify, the need to separate biodiversity from threatening processes. Human behavior, whether intentional or unintentional, legal or illegal, is the primary factor influencing the distribution and numbers of large carnivores in many parts of the world today. Conflicts between humans and wildlife are a growing source of concern for conservationists, particularly with regard to large carnivores, which can kill both livestock and humans.

Non-permeability of unelectrified fences is often difficult to achieve for many species, including elephants, lions, and leopards (Panthera *pardus*), and the effectiveness of electrified fences is highly dependent on maintenance. Human-animal conflict (HAC) and its negative consequences are expected to worsen as the world population grows. They disproportionately affect the rural poor in low-income countries, particularly smallholders in African and South Asian regions with high biodiversity [2]. Farmers have devised a variety of crop-raiding animal mitigation strategies [3]. Smallholders in low-income countries, on the other hand, are largely limited to traditional and low-cost technical measures (e.g., hunting, scaring, building stone or wooden fences) and labor-intensive crop guarding [3], which is a common HAC mitigation strategy.

Human-carnivore conflict is now a common global phenomenon in rural areas, as well as on the outskirts of cities in both developing and developed countries. Human–wildlife interaction and conflict are increasing as the human population and pressure on forest areas grow. It occurs when growing human populations overlap with established wildlife territories, increasing interaction of man and wild animals and thus resulting in increased levels of conflict. Direct wildlife contact occurs in both urban and rural areas, but it is more common inside and around protected areas [4]. Large mammals' movement and ranging patterns are primarily determined by the availability of food, water, escape cover, and mates.

Effective human-elephant Conflict (HEC) mitigation is difficult to understand and difficult to implement; it remains a complex package of seemingly disparate measures that must be used in combination and flexibly at various scales. The mitigation of HEC began in the mid-1990s. The IUCN African Elephant Specialist Group and its human-elephant Conflict Working Group spearheaded the necessary research and subsequent dissemination of tools to address the issue.

2. What are the reasons/causes for increased HAC?

2.1 Habitat Loss

Only 5% of India's geographical area is in the protected area category. This space is not enough to have a full-fledged habitat for wild animals. A territorial animal like a male tiger needs an area of 60–100 sq. km. But the area allocated to an entire tiger reserve, like the Bor Tiger Reserve in Maharashtra, is around 140 sq. km. The territorial animals do not have enough space within reserves and their prey does not have enough fodder to thrive on. This has forced the wild animals to move out and venture close to human habitation in search of food, resulting in HAC.

2.2 Increasing infrastructure development

Recent relaxations in norms to allow for a widening of highway and railway networks near these protected areas are the new threats, adding to the old ones of retaliatory poisoning and poaching. Apart from highways, railway and irrigation projects are coming up in tiger reserves. For example, the Ken-Betwa river interlinking project will submerge 100 sq. km of Panna Tiger Reserve [5].
Also, wildlife experts estimate that 29% of the tigers in India are outside the protected areas.

3. Mitigation strategies

1. Mitigation strategies for human–wildlife conflict differ greatly depending on the location and type of conflict. Although passive, nonintrusive prevention measures are always preferred, active intervention is frequently required in conjunction. Whatever approach is taken, the most successful solutions involve local communities in the planning, implementation, and maintenance. Resolving conflicts often necessitates a regional strategy with a response tailored to the specific crisis. Nonetheless, a variety of management techniques are frequently used to resolve conflicts.

2. *Translocation of problematic animals:* Translocation of problematic animals: Migrating such "challenge" animals from a conflict site to a new location has been used in the past as a mitigation technique, but recent research has shown that this approach can have negative effects on species and is largely ineffective. Translocation can reduce a species' survival rates and lead to extreme dispersal movements, and "problem" animals frequently resume conflict behaviors in their new location.

3. *Erection of fences or other barriers*: Building barriers around cattle sheds, establishing distinct wildlife corridors, and erecting box-shaped fences around farms to deter elephants have all proven to be effective and cost-effective strategies for reducing human–wildlife conflict.

4. *Improving community education and perception of animals:* Different cultures have different perspectives and values on the natural world, and how wildlife is perceived can play a role in exacerbating or alleviating human–wildlife conflict. Conservationists worked with community leaders in one Masaai community to shift perceptions and allow young men to achieve the same social status by protecting lions instead of killing them.

5. *Effective land use planning:* Changes in land use can help to reduce conflict between humans and crop-raiding animals. For example, after discovering that elephants dislike and avoid plants containing capsaicin, communities in Mozambique began to grow more chili pepper plants. This ingenious and effective method both deters elephants from trampling community farmers' fields and protects the species.

6. *Compensation:* In some instances, government entities have been set up to provide budgetary compensation for the damages caused by human–wildlife conflict. These systems hope to reduce the need for retaliatory animal killings by financially enticing the coexistence of humans and wildlife. To name a few, compensation strategies have been used in India, Italy, and South Africa. Compensation's success in managing human–wildlife conflict has varied greatly due to under-compensation, a lack of local participation, or the government's failure to provide timely payments.

7. *Spatial analyses and mapping conflict hotspots:* Human-carnivore conflict and human-elephant conflict, among others, have been successfully mitigated by mapping interactions and developing spatial models. In Kenya, for example,

conservationists were able to establish an effective predictor of human-elephant conflict by combining grid-based geographic information systems with simple statistical analyses.

8. *Predator-deterring guard dogs:* The use of guard dogs to protect livestock from predation has proven to be effective in reducing human-carnivore conflict all over the world. According to a recent review, 15.4 percent of study cases investigating human-carnivore conflict used livestock-guarding dogs as a management technique, with average animal losses 60 times lower than the norm.

9. *Managing garbage and artificial feeding to prevent attraction of wildlife:* Many wildlife species are attracted to garbage, particularly food waste, resulting in negative interactions with humans. Poor garbage disposal, such as hotel waste, is quickly emerging as an important factor contributing to human-carnivore conflicts in countries such as India. Urgent research to increase understanding of the impact of easily accessible garbage is required, as is better garbage management in areas where carnivores live. Managing garbage disposal and artificial primate feeding can also reduce conflicts and disease transmission opportunities. According to one study, preventing tourists from feeding Japanese macaques reduced aggressive interactions between macaques and humans.

10. *Use of technology:* Innovation in technology (particularly in information technology) has the potential to play a critical role in the prevention of human–wildlife conflict. Drones and smartphone applications can be used to recognize animal movements and alert highway and railway authorities to prevent animal collisions with vehicles and trains. SMS and WhatsApp messaging systems have also been used to notify people of the presence of animals in the surrounding area. Early warning wireless systems have been used successfully in undulating and flat terrain in Tamil Nadu, India, to reduce human-elephant conflict.

4. Main types of human–wildlife conflicts

With species that are abundant and viewed as pests, extensively managed, or even domesticated, and live in a variety of environments, human–wildlife conflict and coexistence do occur. It should come as no surprise that much research on human–wildlife conflict has concentrated on endangered species. The protection of endangered species and the requirements of local communities must be balanced, which is why many conservation methods include conflict resolution as a key component. The following examples high lightened the effects of typical types of human–wildlife interactions.

4.1 Leopard–human conflicts

In order to retain local support for leopard protection, human killing must be dealt carefully as it is the ultimate and most significant expression of human–leopard conflict. The remote mountain and foothill regions of central and south Asia are the only places where leopards can be found. They can be found in tropical forests, meadows, mountain temperate forests, and locations that are adjacent to cities, where they have access to prey species and some cover to hide in. Athreya and Belsare [6] suggested that they are still thriving in locations where other big cats have been eradicated due to their less specialized diet than other felids. It has previously been considered a common species because of its extensive geographic range and low priority status for conservation.

4.1.1 Biology of the species related to conflict

- Leopards are solitary
- Leopards are territorial
- Leopards are very adaptable and can live near human inhabitations
- Leopards are known to feed on domestic dogs and livestock

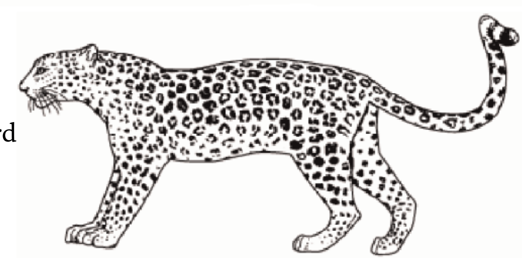
Scientists do not advise translocation to resolve leopard conflict because Leopards might spread conflict or start it close to the new release site; following translocation, particularly the elderly leopards, make an effort to return to their homes. Increased leopard populations in the nearby human-dominated areas could result from sustained translocation into a particular forest.

Eight subspecies of the leopard are presently classified by the IUCN Red List as threatened, meaning they are either "endangered" or "critically endangered." The leopard has been eliminated from a sizable portion of its historical range due to habitat degradation, a decline in natural prey, and direct human harassment.

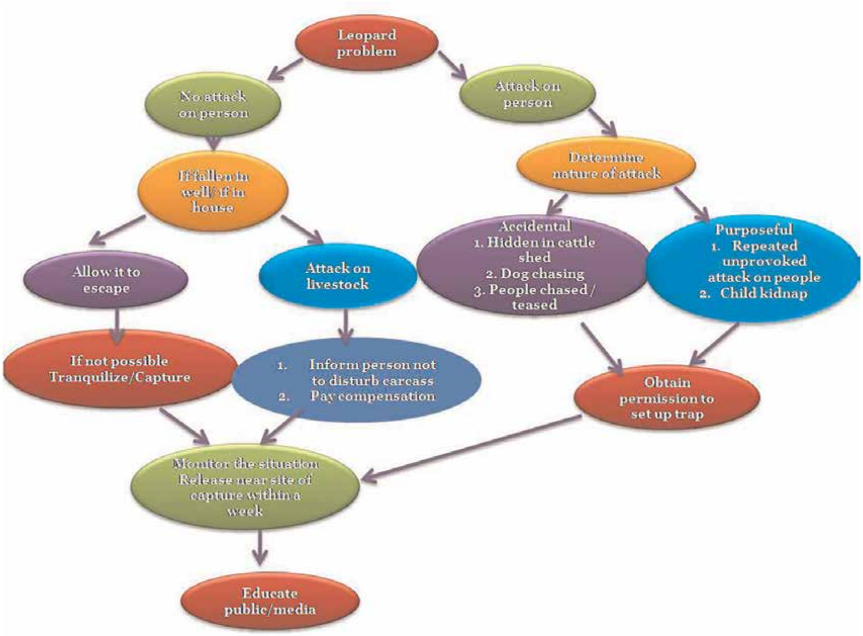
Livestock raising is a crucial component of the local economy in the majority of developing nations. Particularly the underprivileged locals graze their cattle in or next to forests and protected areas. Commonly used strikes grazing livestock in wooded areas as well when hazards to people are present within human settlements also exist [7].

Tiger

Leopard



4.1.2 Mitigation for human leopard conflict



1. People who live close to forested areas should refrain from keeping pets since they attract leopards.

2. People who live close to forested regions should avoid wandering at dawn and twilight when leopard attacks are frequently anticipated.

3. To protect natural ecosystems from exploitation and to prevent human intervention in such regions, appropriate legislative measures should be applied.

4. When challenged by locals outside of their natural environments, wild carnivores typically unleash panic as retaliatory and protective action. Therefore, it is best to refrain from bothering animals away from their natural environments.

5. Despite years of coexisting with nature, people's understanding of the ecology and behavior of wild animals is astonishingly limited. Governmental and nongovernmental organizations must therefore step forward to plan awareness campaigns. Activities including instruction and training will aid in fostering tolerance for wild animals. Training and teaching programs for wildlife employees that provide the necessary knowledge for interacting with wild carnivores would encourage conservation commitment and improve the welfare of animals.

6. The state government has increased victim compensation due to the rising number of man-animal conflict cases. The management of wild predators outside of their natural habitats also requires the organization of training programs for wildlife officials.

7. The amount of forest cover has either reduced or declined in quality as a result of habitat degradation brought on by the increasing human population, shifting

land use practices, and resulting anthropogenic stressors. Long-term conflict rates can be significantly decreased by avoiding deforestation and increasing the number of trees planted in forest areas.

4.1.3 A guide to identifying leopard attacks

- Wolf, leopard, and hyena are examples of wild carnivores that dwell in and around highly populated human settlements.
- The species responsible for an attack on a person or a piece of livestock must be appropriately identified. For instance, trap cages should not be set up if a wolf is to blame.
- Wolves avoid traps and cages. However, setting up a trap cage will probably trap a leopard, resulting in an unwanted capture.
- The following information will help you identify the family (dog or cat) who attacked you.
- Pugmarks, information on the method of attack or killing, and information from trustworthy eyewitnesses can all be used to learn more about the species.
- It must be remembered that the following are merely recommendations and that it is frequently challenging to gather precise information from the signals in the field.

Leopard.	**Wolf, Hyaena**
	
• Pugmarks squarish • Pugmarks are usually without claw marks	• Pugmark elongate • Pugmarks with claw marks

4.2 Human-tiger conflicts

Despite the necessity to promote coexistence and the prevalence of conflicts between humans and large animals, few studies have actually made an effort to put conflict reduction techniques into practice and assess their efficacy. Locals commonly feel as though their knowledge and opinions regarding conflicts between people and wildlife are being disregarded, which undermines support for initiatives like the Livestock Insurance Fund.

Human-tiger conflicts can be grouped into 3 categories:

1. Tiger attacks humans

2. Tiger attacks domestic animals

3. Tigers that approach human-dominated areas

Tigers may target people as prey, but most of the time they do it out of self-defense to protect their cubs or themselves, particularly if they have already been hurt by people. Tigers generally prey on domestic animals, especially in areas where there are few wild predators to catch them. Although the existence of tigers in regions where humans predominate is not always a recipe for conflict, it may be. Because of this, the local populace closely monitors such events and frequently requests government intervention.

If nothing is done to stop these incidents, as tiger numbers increase, the number of fatalities may also increase. Even though these rates of mortality are minimal in comparison to other factors that affect human populations, the economic and emotional toll on local people is significant and can have a negative impact on efforts to conserve tigers. In regions where wild prey is scarce due to hunting, habitat degradation, and competition with livestock, tigers routinely kill livestock and dogs.

4.2.1 Principles to improve human-Tiger conflicts

The human-tiger Conflict has been addressed using a variety of strategies. They can be broadly divided into four groups:

1. *Preventative measure*s, or those intended to stop or lessen conflict before it occurs;

2. *Mitigative measures*, or those intended to lessen the effects of conflict after it has already occurred.

3. *Reactive actions* or those conducted to stop a specific, continuing occurrence;

4. *Integrated programs*, those that are a part of most or all other actions; and Reactive measures;

4.2.1.1 Preventative measures

A. Improved livestock management

    i. Except for situations where tigers stray into landscapes occupied by humans, depredation of livestock will cease if livestock grazing is prohibited within tiger habitat.

ii. Fencing around cattle enclosures used at night to keep them safe from attacks by tigers and other animals has proven to be effective.

iii. Due to tigers' aversion to open spaces, the vegetation cover around the enclosures might be lowered.

iv. Because buffalo defend themselves against predators, keeping them alongside cattle may lessen predation, but it will not completely solve the issue because tigers have been known to kill buffalo.

v. Reducing the number of cattle might assist to prevent disputes, but without strong incentives, people are unlikely to willingly reduce their livestock herds.

B. Management of wild prey

a. Tiger attacks on livestock and people may increase if there is a lack of natural prey.

b. Site-specific measures to boost prey populations may include increased law enforcement and legislative reform to decrease overharvest, lessening competition with cattle, and protecting and restoring habitat [8]

c. Tiger availability must be reduced while efforts are made to boost wild prey; otherwise, livestock predation may grow as tiger density and reproduction rise.

C. Zoning

i. Human relocation initiatives must be open, fair, and incentive-driven with the aim of separating people and their livestock from vital tiger habitats and transit routes whenever possible.

ii. Removing humans and animals from tiger habitats can stop human-tiger conflict, lessen habitat fragmentation, and aid in the recovery of the prey population.

iii. But this must be weighed against the requirement for migration routes between vital tiger habitats. That is, agricultural lands with sharp edges, like oil palm plantations, act as a barrier to the passage of tigers.

iv. If these areas entirely encircle crucial ecosystems, the tiger populations there will be genetically isolated.

D. Reducing injuries to tigers

1. Tigers and other large cats are sometimes injured when they attack people or cattle, and the wounds are frequently caused by snares, traps, or gunshots.

2. Snares set for other animals, such as wild pigs, are frequently used to catch tigers.

3. Poaching prevention, snare removal, and other initiatives that lessen the frequency of tiger injuries will aid in lowering.

E. Other preventative measures

i. Tiger assaults have been deterred by wearing masks on the back of the head and protective helmets, and tigers have been trained to avoid attacking people by using electrified mannequins.

ii. Although dogs have been employed to alert humans to the presence of tigers, in Russia, tigers have attacked many people while trying to feed on dogs.

iii. In Russia, tigers have been effectively deterred from attacking using handheld flares and pepper spray.

4.2.2 Programs that mitigate the impacts of human-tiger conflicts

4.2.2.1 Compensation and insurance programs

a. Compensation programs compensate livestock losses due to predation, medical expenses when people are attacked, and family compensation when a life is lost.

b. Compensation programs typically aim to improve local acceptance of tigers and, as a result, reduce retaliation killing, but with varying degrees of success.

c. Failure reasons include unsustainable high payout costs, difficulty verifying claims, a large number of false claims, government corruption, and the difficulty of making timely payments in rural areas.

d. In terms of compensation for human deaths, it is difficult, and some believe immoral, to place a monetary value on human life; however, failing to compensate for human life loss may give the impression of an extremely indifferent conservation community.

e. Compensation programs offer compensation for livestock losses from theft and medical costs incurred when humans are attacked. Due to the indiscriminate nature of the tactics employed for retribution killing (such as snaring, poisoning, and explosive traps), compensating merely for damage caused by tigers may not diminish tiger reprisal killing.

f. For these reasons, compensation programs are not advised for livestock depredation; nevertheless, if they are employed, they should only offer compensation in situations where there is still depredation despite effective livestock management techniques.

g. Similar issues affect insurance systems, and there is also the issue of a shortage of private insurance providers ready to provide livestock depredation insurance at competitive rates.

h. Insurance payouts must be linked to livestock management strategies that reduce depredation, much like compensation.

4.2.2.2 Incentives programs

a. Through alternative income streams based on "conservation-friendly" activities, such as improved livestock management, incentive programs aim to offset the costs of depredation.

b. Because it has never been proven that incentive programs have a positive effect on tiger populations, the effectiveness of incentives programs as tiger conservation measures is unknown.

c. Incentives programs have also been employed to conserve snow leopards in a number of nations, with success in raising local incomes and increasing the density of natural prey.

d. All of these initiatives are supported, at least initially, although some, like those of the Snow Leopard Trust, have become self-sustaining.

4.2.2.3 Reactive measures

1. A number of issues, including a lack of space, illness, damage, and senility, can occasionally lead to lone tigers entering villages and/or attacking domestic animals or people.

2. Mechanisms for resolving individual conflicts are required wherever tiger populations are present. Lethal control and removal from the wild are the most frequently utilized strategies historically and currently, and both have the same effect on the wild population—namely, lower survival rates.

3. Tigers are occasionally taken out of the wild unnecessarily, and it is frequently difficult to tell whether the tiger that was killed or captured was the offending animal.

4. A variety of nonlethal techniques, such as visual and acoustic deterrents (such as fireworks, signal flares, cracker shells, lights, and sirens), projectiles (such as rubber bullets), protective collars on livestock, and conditioned taste aversion, have been used by carnivores in response to specific conflicts.

5. In cases of human-animal conflict, measures are taken such as scaring the tiger away from the area, capturing it, fitting it with a telemetry device, and releasing or moving it.

6. Telemetry enables managers to keep an eye on the tiger, giving early notice if it tries to approach people or livestock and offering a way to gauge the effectiveness of actions.

7. Young animals, frequently orphaned when their mothers are poached, are frequently believed to be too young to live and are caught, however cubs as young as seven months have survived in the wild without assistance and can sometimes be maintained through feeding programs.

8. Decisions to translocate a tiger, release it onsite, or remove it from the wild must consider the degree of certainty that the captured animal is the offending animal, individual tiger characteristics such as age, sex, physical condition, behavior, and residency status, as well as the availability of suitable release sites, appropriate equipment to capture and transport tigers, and holding facilities for captured animals.

9. Young, dispersal-age tigers are thought to be the best candidates for translocation because these animals are constantly wandering through new habitats.

10. The decision-making process for managing with human-tiger conflict occurrences is complicated, involving a number of biological, social, and political factors (**Figure 1**). Individual HTC scenarios would be best handled by a team of trained professionals following a set methodology. Tiger response teams should have specific protocols to help them make decisions, as shown in **Figure 1** for domestic animal depredations.

4.2.2.4 Integrated programs: education and community involvement

i. Most projects will necessitate an educational component, which may be provided as part of a broader tiger conservation education campaign or as part of a specific effort to decrease conflict.

ii. Education will be an important component of programs to enhance livestock management as well as compensation, insurance, and incentive programs, as the latter must be directly tied to changes in human behavior that benefit tigers.

iii. Human conduct during a tiger encounter can avoid an attack, so training humans how to react when confronted with tigers is essential.

iv. Furthermore, people should be educated on tiger conservation regulations, as well as their rights and obligations in relation to human-tiger Conflict.

4.3 Human-elephant conflicts

In elephant range countries, human-elephant conflict is a key conservation concern. A range of management solutions for preventing and minimizing human-elephant conflict have been developed and are used at various scales. However, human-elephant conflict persists because most present prevention measures are driven by site-specific factors that only provide short-term solutions, while mitigation strategies frequently transfer conflict risk from one location to another.

Human settlements and agricultural fields have expanded across Asia and Africa, resulting in extensive loss of elephant habitat, deteriorated fodder, reduced landscape

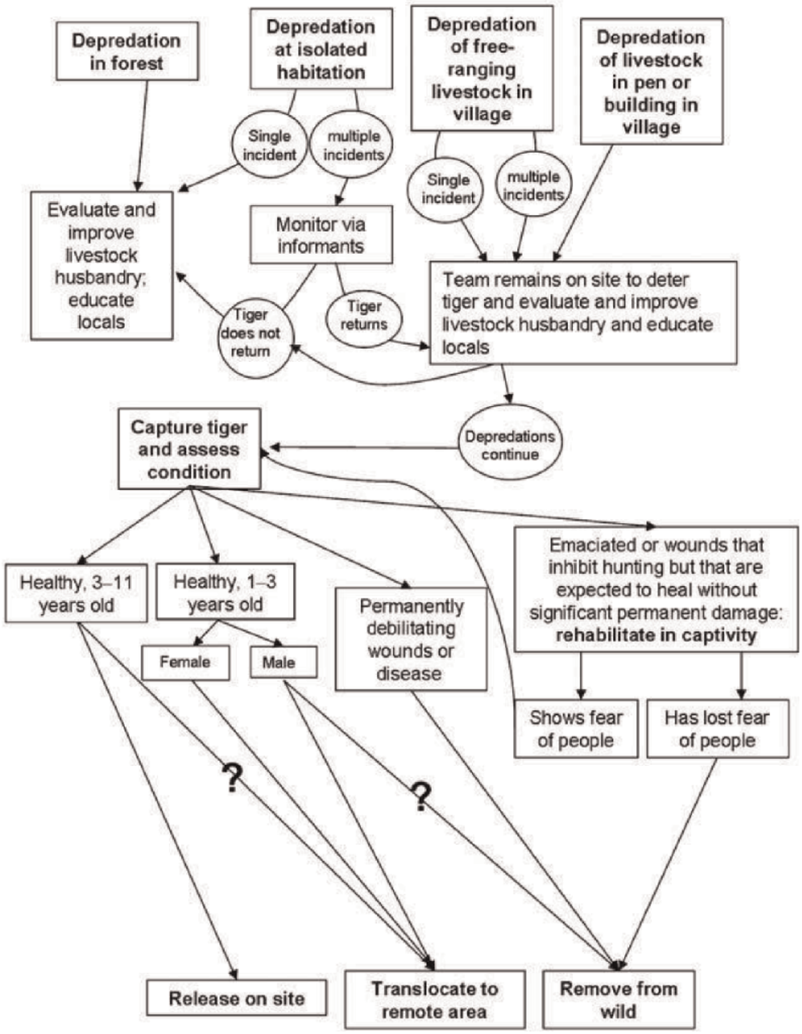


Figure 1.
Decision-making chart for livestock depredations (image courtesy Goodrich, [9]).

connectivity, and a considerable decline in elephant populations relative to their historical size and overall range. Elephants are increasingly brought into greater contact with humans as their habitats shrink, resulting in more frequent and severe conflict over space and resources, with repercussions ranging from crop raiding to reciprocal loss of life.

Human-elephant conflict has become a concern to biodiversity conservation, and conflict resolution is a top priority for elephant conservation in range countries. Growing understandings of wildlife behavior and the spatiotemporal patterns of human–wildlife conflict have resulted in the suggestion, development, and implementation of a wide range of prevention and mitigation strategies. Current conflict resolution strategies emphasize isolation and on-site deterrents, as well as mitigation through elephant translocation or selective culling and monetary compensation for losses.

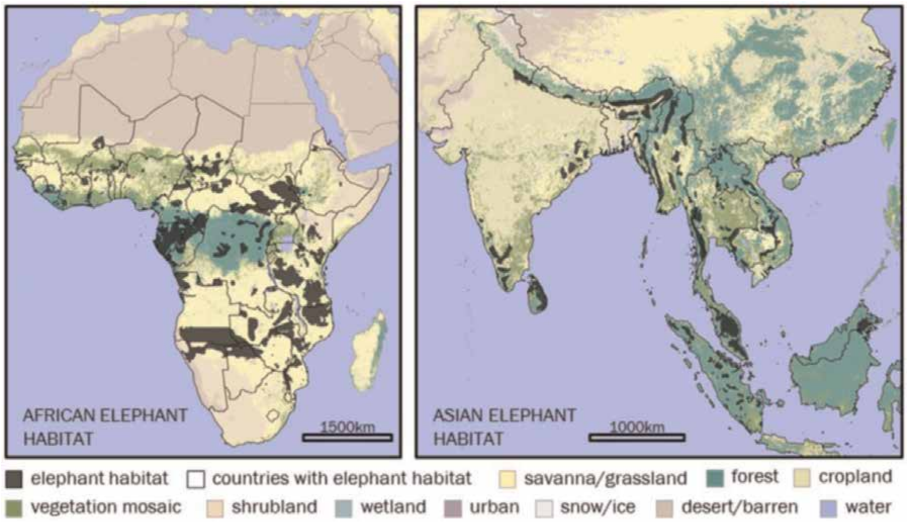


Figure 2.
Global elephant species distribution map. Land cover based on a 500-m resolution mode value MODIS land cover type product (MCD12Q1) from NASA, 2000–2016 [10] (Friedl et al. [11]; elephant population data).

However, most management measures only address the symptoms of human-elephant conflict, rather than the underlying causes of conflict such as cultural values, resource use decisions, and the increasing fragmentation and isolation of elephant populations.

The Elephantidae family historically spanned the American, European, Asian, and African continents, but it now only exists in Asia and Sub-Saharan Africa (**Figure 2**). Extant Asian elephants (Elephas maximus) are listed as endangered by the International Union for Conservation of Nature (IUCN), and African savanna (*Loxodonta africana*) and forest (*Loxodonta cyclotis*) elephant species are listed as vulnerable [10].

4.3.1 The causes and result of human-elephant conflict

Human-elephant conflict is a critical concern for ensuring elephant survival and persistence in their range countries, as these are also regions where the development and well-being of human groups sharing space with these mega-herbivores are crucial. As humans alter the landscape, bringing human and elephant populations closer together, the potential of conflict increases, with often catastrophic consequences. In India alone, conflict episodes kill 400 people and 100 elephants each year, with crop raiding affecting an additional 500,000 families. Every year, Sri Lanka records around 70 human and 200 elephant deaths as a result of warfare. Illegal ivory poaching complicates projections for elephant losses in Africa.

During dry years, many rural populations relocate to more permanent water sources to provide consistent water supplies for their household needs, crops, and livestock.

However, competition for increasingly scarce water sources and other resources during and/or after droughts increase the potential of elephant-human conflict.

a. Poverty affects household buffering ability and evolutionary capacity to respond to crop-raiding elephant harvest losses, further undermining conservation efforts by instilling intolerance and prejudice against elephants.

b. Humans, like elephants, are ecosystem engineers who have a significant impact on their surroundings. Through direct and indirect competition for water, food, and space, their subsistence activities limit elephant home range and population density.

c. Farmers and pastoralists influence biophysical dynamics and habitat patterns through subsistence agriculture output and resource management.

d. Elephants may be attracted to patches of fresh vegetative growth when trees are cut down and burned to make room for agricultural expansion and increase livestock fodder.

e. Fields being planted close to water sources and holes being dug to access groundwater may change elephant travel paths

f. Habitat fragmentation increases the likelihood of human-elephant conflict because the roads and farms that surround fragmented feeding places are more prone to host hostilities.

g. Crop destruction and human casualties are the two most frequently recorded and widely publicized costs of conflict, but less obvious costs, such as lowered mental well-being and disrupted social activities, raise more questions.

4.3.2 Strategies for conflict prevention and mitigation

4.3.2.1 Conflict resolution techniques

a. Methods of Exclusion.

    i. Ecological pathways and protected areas

    - Wildlife conservation is now linked with the physical separation of humans and wildlife owing to the creation of protected areas and the work of conservationists and wildlife managers. Ecological corridors connect isolated protected areas and fragmented habitats, promote herd connectedness, provide demographic rescue benefits, and improve gene flow.

    - Furthermore, ecological corridors or even fencing for protected areas may lead to "green grabbing," in which subsistence farmers are denied access to privately or communally held arable lands along elephant migration routes that are walled off to lessen conflict between people and elephants without receiving just compensation.

    - Therefore, deeper comprehension of human-driven land use change is required, along with a greater awareness of how it may affect elephant habitat, connectivity, and migratory patterns.

b. Trenches and electric fences.

- In order to prevent elephants from invading agriculture and populated areas, physical exclusion techniques like electric fences and trenches are frequently deployed.

- The use of these physical barriers at a broader scale is hampered by the expensive construction and ongoing maintenance costs, particularly in fragmented landscapes with considerable frontage to farms and forests.

- Design, responses to reports of fence breaks and fence-breaking animals, as well as general enforcement and management, may all work against long-term efficacy.

- According to studies, African elephants may try to break an electric fence that surrounds them if they discover that their tusks do not carry electricity, causing the fence to sustain expensive damage.

- Physical obstacles can have a negative impact on long-term survival because they further isolate already dispersed elephant populations, obstruct movement and access to seasonal food and water supplies, and restrict the exchange of genes across herds. In Asia, the efficiency of fencing has mostly gone untapped.

c. Other techniques.

4.3.2.2 Acoustic barriers

Farmers use loud noises, firecrackers or carbide cannons, smashing metal objects, throwing stones, and yelling to protect their crops and scare away elephants that might raid them. While these methods are efficient in preventing elephants from damaging crops, they also interfere with farmers' livelihoods and psychosocial well-being. The use of high-tech acoustic deterrents is still challenging. Only short-term and short-distance elephant repellant tests have been conducted using audio play-backs of ominous noises such as wild cat growls, human yells, and vocalizations from matriarchal groups of elephants.

According to some research, elephants adapt rapidly to these noises and come back to plunder farms. Additionally, these playback systems require logistical problems to install, regularly monitor, and maintain in remote locations.

Although the experiments conducted indicated that audio playbacks were 65–100% effective, the potential adverse effects on other species warrant more investigation before widespread adoption.

Recent research in Africa provide encouraging outcomes when elephants are repelled by bioacoustic techniques like beehive fences, which also help pollinators and honeybee habitats.

4.3.2.3 Light-based dissuaders

To protect maturing crops and fend off attacking elephants, farmers may start bonfires and use fiery torches or spotlights. A small number of communal fields have been tried with solar spotlights, which are shone in elephants' eyes to scare them away from agricultural fields; nevertheless, initial purchase prices restrict widespread adoption by low-income rural households and communities.

Like acoustic deterrents, light-based deterrents are temporary fixes that lose their potency over time when elephants become accustomed to them or relocate to other areas.

4.3.2.4 Agriculture-based deterrents

Agriculture-based deterrents like chili-greased fences and chili dung have not seen as much testing or use as exclusion, acoustic, and light techniques [12].

There is a wide range in the effectiveness of chile deterrents, from little effect to modest reduction in crop-raiding, according to recent field testing. Furthermore, this method is unaffordable for many communities due to high application and maintenance costs.

4.3.2.5 Early identification and alert

Using mobile phones to quickly communicate among farmers and between farmers and local officials is one method for early elephant discovery and warning. This technique encourages collaboration in chasing away possibly troublesome elephants.

In order to recognize and locate people over great distances, elephants employ infrasonic cries, which early warning systems may incorporate by placing detectors in conflict-prone areas. However, in order for these gadgets to send alerts to farmers, they need to be connected to the internet or have network coverage, which makes infrasonic receivers less useful in distant locations.

Similar to radio-collared elephants, satellite tracking enables early warning of potentially troublesome individuals and herds.

4.3.3 Conflict resolution techniques

Affected farmers and local people may request a response from government bodies or nongovernmental groups that deal with elephant conservation after a human-elephant conflict occurrence to lessen potential conflict in the future [13].

The taming, culling, and relocation of troublesome individual elephants or herds are covered in detail below. The topic of conflict mitigation initiatives that financially make up for lost crops or lives is then covered.

4.3.3.1 Translocation

Problematic elephants are drugged, rendered immobile, and transported from farms or human settlements to PAs for release. Initial findings indicate that translocated elephants frequently return to their original territory and tend to spread conflict around the release area as they move toward their original home range, even though the effectiveness and long-term feedback of elephant translocation have not been thoroughly tested. Additionally, translocation frequently defeats conservation objectives due to increased mortality rates for elephants during capture and transportation, as well as occasionally deliberate killing in the release region.

4.3.3.2 Domestication

Domestication methods have been used in Asia for a very long time to reduce or even end hostilities between people and elephants. Although Asian elephants can reproduce in captivity, it is best to capture and domesticate wild females. Asian elephants that were captured and domesticated have integrated well into human society. They currently perform ceremonial duties in temples and at community events, haul heavy loads for use in agriculture, settling disputes, and going on hunting expeditions, and assist in the capture of other wild elephants.

Human-elephant conflict and the resulting negative attitudes toward species conservation are likely influenced by the loss of these beneficial human-elephant relationships in local communities and effective management of wild populations.

4.3.3.3 Compensation

- More market-based methods of reducing human-elephant conflict give individuals harmed financial recompense. The views and attitudes of people who live in conflict-prone areas are essential to the management of human-elephant conflicts, and recouping economic losses helps to promote tolerance for elephants and positive attitudes toward animals.

- In order to get compensation, the property damage and/or loss must first be reported to park officials or another appropriate local authority, who will then conduct a visual inspection of the damage. Conflict and corruption are made possible by the absence of uniform assessment criteria and payment methods.

- Compensation plans frequently focus on the market price for the crops and livestock losses suffered by victims without taking into account the opportunity costs of conflict resolution, the transaction costs of receiving compensation, or the unaddressed costs of decreased psychosocial and social wellbeing. Additionally, it is challenging to put a financial value on and adequately compensate people who have been killed or injured by elephants.

- However, compensation schemes have not been as effective in reducing human-elephant conflict as they have been in other situations where successful compensatory programs have raised tolerance toward violent species.

- Due to inadequate compensation, logistical difficulties, weak governance, a lack of transparency, limited local understanding of the program's scope and limitations, and bogus claims, compensating schemes sometimes face harsh criticism in nations where elephants roam.

- However, monetary compensation for the harm done does not address the conflict's fundamental roots, and as a result, does not seem to be a workable or long-term solution.

4.3.3.4 Culling

Elephants that pose a persistent threat to communities, particularly those that have killed people, are regularly slaughtered to allay grievances and stop further conflicts and losses in both Asia and Africa. Africa often employs the slaughter of crop-robbing elephants or those that attack humans to control elephant populations and reduce human-elephant conflict, in contrast to Asia's emphasis on domestication. African culling customs have their origins in both pre-Colonial and colonial elephant hunting, which helped to ensure food security by supplying affected people with meat and by reducing competition for scarce resources. It also provided ivory for sale. Elephants in southern and eastern Africa were more frequently killed for their ivory as the demand for ivory from the continent increased due to culling for mitigation.

It is debatable and disputed whether culling is effective or necessary for preserving elephant populations and reducing conflict because it mostly targets male elephants because of their large territorial ranges that bring them near to human habitations.

4.3.4 A theory-based model for reducing and mitigating human elephant conflict

The dependence of both species is increased by ongoing and upcoming changes to land use, conservation policy, economic markets, climate issue, and other disruptions. The coexistence of humans and elephants rather than their conflict is the focus of effective strategic planning, which also addresses the fundamental causes of conflict and their spatial variation as well as the overlapping and changing requirements of both species. As per Shaffer et al. [14], conceptual model, which builds on previous work, focuses on encouraging peaceful coexistence and minimizing conflict through landscape-level planning guided by open-data and tools, ethnographic data, and community-based education and mitigation strategies.

Conflict between humans and elephants is caused by the intersection of biophysical processes, livelihood activities, and species population dynamics. The sizes, densities, rates of growth, and frequent movements of elephant herds have an immediate impact on the places, times, and levels of conflict. This intensity takes into account the perceived hazards to human safety as well as the degree of harm done to a home or community and its capacity to withstand more conflict (**Figures 3** and **4**).

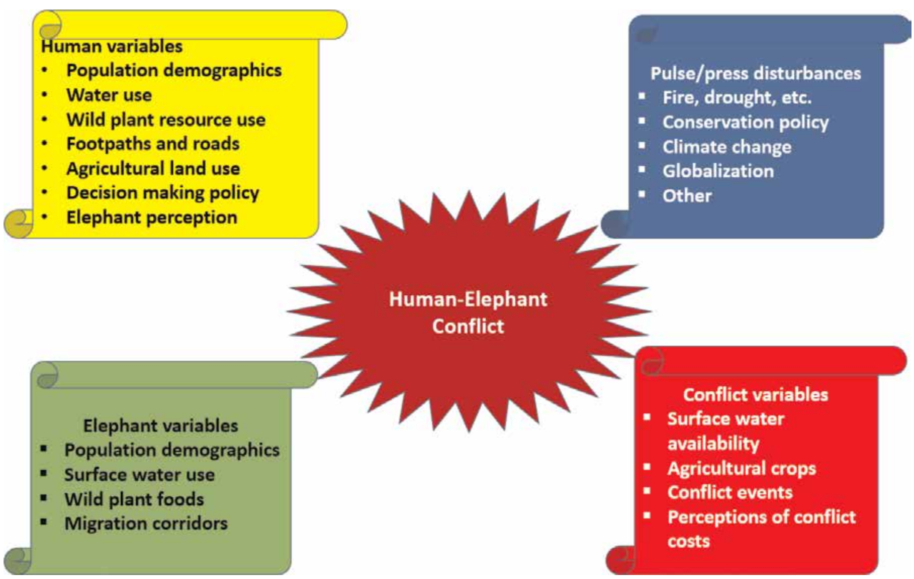


Figure 3.
Image courtesy Shaffer et al. [14]. Human-elephant conflict: a review of current management strategies and future directions.

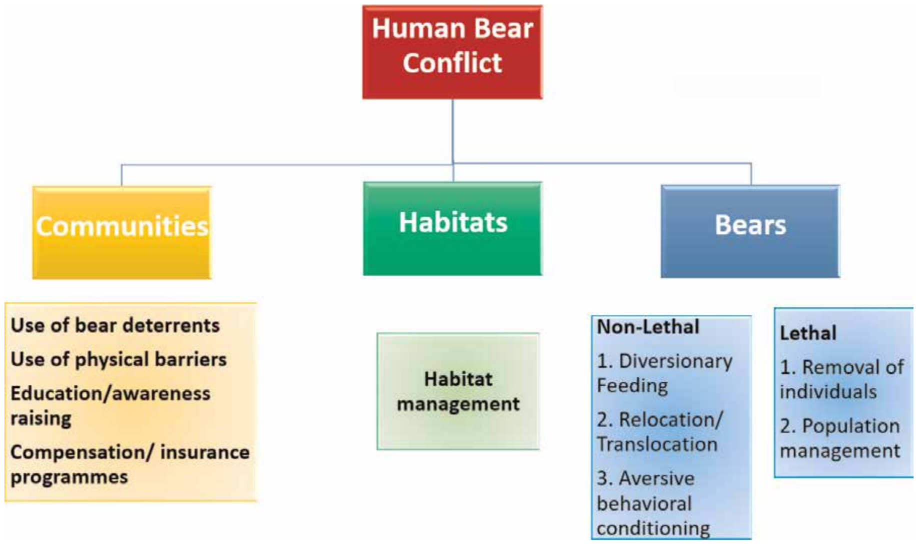


Figure 4.
Human-bear conflict management plan [15].

However, burn techniques to manage landscapes are pulse events. On the opposite side of the conflict equation, human population dynamics directly influence land usage and resource access during livelihood activities. Decisions about land use and resource access, conflict resolution strategies, perceived risks, and ultimately the sustainability of any initiatives taken to lessen or prevent future conflict are influenced by historical changes to livelihood practices brought on by sociocultural, economic, political, climate, and biophysical changes.

According to site-specific data on attitudes toward elephants and the costs of conflict, it is possible to restructure mitigation and educational programs or introduce new opportunities in areas where communities can profit from the presence of elephants to foster tolerance and increase appreciation for elephants. This data must be gathered objectively, with "boots on the ground," by observing and learning about the needs and decision-making processes of the community, as well as by identifying local residents who can take the lead in co-creating, co-implementing, and co-managing long-term conflict reduction strategies in their communities.

Therefore, in a coupled natural and human system, the adaptive capacity, resilience, and vulnerability of a variety of biophysical and social components, and the processes that link them together, are crucial for the conservation and long-term sustainability of coexisting human and elephant populations. Our conceptual model focuses on resource rivalry and the ensuing conflict between humans and elephants over access to water, food, and space. Additionally, it discusses press and pulse disruption processes that affect the competition for human and elephant resources.

Alternative tactics may be suggested if conflict hotspots and areas of shared resource usage have been discovered by landscape modeling that incorporates data from both natural and human systems. In order to maintain appropriate water availability during dry years, strategies could include digging new wells and constructing boreholes for human populations or developing new water sources along known elephant migration pathways that could detour these animals away from human regions. Communities could collaborate with governmental organizations and nongovernmental organizations to create policies and programs that safeguard crucial elephant range areas and ecological corridors while promoting human well-being by creating new employment opportunities and ensuring sustainable access to resources that are significant to local culture.

4.4 Human-bear conflict

Conflicts between people and bears appear to have received less attention globally than disputes involving other big predators like felids and canids. On four continents, millions of humans coexist with bears; some do so happily, while others must deal with protracted disputes. Conflicts between locally or globally endangered animals create questions about conservation. "Any circumstance where wild bears utilize or damage human property; where wild bears harm people; or where people believe bears to be a direct threat to their property or safety" is what we refer to as a "human-bear conflict".

Sloth bears are notoriously vicious animals. Sloth bears are among the most feared of all wild creatures in central India, where they have a dreadful reputation. Particularly when the mother and cubs are present, they are incredibly unpredictable when it comes to attacking people. Conflict between humans and bears has been documented all across the world. The Asiatic black bear, one of the main mammals of the Himalayan woods, coexists in its habitat with a wide variety of other plant and animal species.

The Asiatic black bear has been reported to be widely spread throughout southern and eastern Asia, with scattered populations in Taiwan and Baluchistan Province of Iran in the west and Indo-China in the east to much of China, Korea, and Japan [16].

Bears typically attacked when they were suddenly confronted, and the attacks were presumably a defensive reaction. Attacks on people engaged in different activities were more likely to occur when they used varied environments more intensely.

Future human-bear conflict management projects should take following points into account.

1. According to a review of conflict management plans, actions targeted at communities (such as deterrents, physical barriers, education/awareness campaigns, and compensation/insurance programs), habitats (such as habitat management), and bears (such as diversionary feeding, relocation/translocation, aversive behavioral conditioning, removal of specific individuals, and population management) make up conflict mitigation

2. The following five characteristics were also discovered through our critical evaluation and should be taken into account in upcoming conflict management activities

4.4.1 Conflict between humans and bears

- In regions where killing bears threaten their survival, incentives must be developed to promote tolerance among local groups. Bears fit well into the biodiversity effects compensation model, which matches conservation issues with appropriate remedies.

- It emphasizes a ladder of mitigation approaches, from removing the problematic animal to compensating the impacted stakeholder. One tactic for promoting coexistence is to recompense those who have been harmed by carnivores [17].

- Financial incentives should be adapted to each context in order to balance people's cultural and economic requirements while achieving the intended conservation goals. Conflict management programs can be modified to include payments for environmental services.

4.4.2 Community involvement in conflict management

- The public's confidence that bear supervisors are acting to ensure public safety and that impacted local stakeholders participate in the conflict management process by effectively preserving their property are both crucial for conservation [18].

- In North America, responsibility sharing is seen as a crucial component of success in conflict management.

- In South America and Asia, forming partnerships between management, locals, and conservationists is crucial since rural residents there would otherwise interpret conservation efforts as punitive limits on their use of the land, imposed by the government or foreigners.

4.4.3 Welfare aspect of conflict and its management

- Although this is pertinent to every planned action that might have an impact on bears, the management plans for human-bear conflicts said little about bear wellbeing.

- The ethical aspects of conservation research have frequently been overlooked, in contrast to other academic disciplines (such as medicine), despite the fact that they constitute a crucial part of conservation biology.

- Populations are at the heart of conservation, but since these populations are emergent characteristics of particular persons, their wellbeing is not only important but also better understood by the general public than is the case with abstract populations.

- Even if it is difficult, it is important to consider the welfare effects of conflict. Many of the behavioral processes relevant to conservation are also of interest to welfare science.

4.4.4 Effectiveness of educational initiatives

- The most frequently mentioned strategy for resolving human-bear conflict is education. The goal of public education should be to raise awareness and aid in the prevention of collisions, damage, and injuries.

- Making conservation education effective is a subject that deserves additional research because not all educational initiatives result in the intended behavioral change. The process of education should be dynamic and interactive, and new instruments must be created and their efficacy tested.

- Wildlife authorities should tailor education campaigns to specific sectors of society by identifying and addressing their values and then monitor results by documenting both failures and achievements within the context of adaptive management.

4.4.5 Improving human-bear conflict management plans

- Organizational clarity would be improved by using graphic designs and logical schemata more frequently [19].

- Plans for managing conflicts between humans and bears could be categorized as logic models, which are instruments for arranging data in an if-then chain of interaction relationships. A logic model identifies a list of steps that must be done, specifies feasible results, and guarantees that these results ensure the desired result.

- Plans need to be clear about each action's execution in terms of where, when, and who will be responsible for it. Within this framework, a human-bear conflict management strategy should be clear about the vision, goals, objectives, activities, outcomes, and outputs as well as the frameworks for institutional and individual accountability.

4.4.6 Policy implications regarding human bear conflict

- Depending on the species, the demands of the population, the priorities of wildlife agencies, and the accessibility of different conflict management components, policy objectives for managing human-bear conflicts may vary from one region to another. Whatever the policy goals, reducing bear conflicts—and human–wildlife conflict in general—will depend on a comprehensive strategy that is sensitive to both human requirements and bear needs.

- International conservation organizations and institutions must encourage and support conflict management in regions where it is a threat to bear populations, and organizations like the IUCN and the World Bank for International Development must assist governments and rural communities in managing conflicts.

- It is necessary for wildlife agencies in charge of bear protection, particularly in South America and Asia, to actively include local stakeholders in methods that promote tolerance for bears and other nearby animals.

- When interacting with colleagues in the developing world, it is equally important for those who work in regions with better infrastructure and technological capabilities to apply the best knowledge in a prudent, realistic, sensitive, and, above all, useful manner to their very different work environments.

- We all share the desire to promote the cohabitation of bears and humans on a global scale, and while comparable concepts may help to achieve this aim, for them to be effective, they must be cleverly tailored to local conditions.

4.5 Human-rhinoceros conflict

The greater one-horned rhinoceros (Rhinoceros unicornis), one of the five remaining rhinoceros species, had its status changed from "endangered" to "vulnerable" by the International Union for Conservation of Nature (IUCN) in 2008. Asian rhino species like to live on alluvial plain grasslands, as well as nearby swamps and woodlands, where there is year-round access to water and lush vegetation. Between the Indo-Myanmar border in the east to the Sindh River Basin, Pakistan in the west, they were once common throughout the northern flood plains and close to the foothills of the Indian subcontinent.

Conflict between people and wildlife must be resolved in order to protect rhino populations and local communities way of life. To address the issues of human–wildlife conflict, local people's involvement and their collaboration with PA officials are essential. Conflict between people and animals can be resolved in a way that benefits both the residents and the rhinos.

Indian rhinos, also known as Greater one-horned rhinos, are arguably the most ancient species of rhino. Their skin resembles a thick armor plate and is similar to that of dinosaurs. But what distinguishes and sets them apart from other rhino species is the single horn. Greater one-horned rhinos are classified as vulnerable, as opposed to the critically endangered black rhinos, mostly because to the decreased threat of poaching.

4.5.1 Reason for huma rhino conflict

Elephants favored all crop kinds in a mature stage of growth and specifically harmed rice, maize, and wheat. Contrarily, rhinos preferred wheat over rice, and like antelope and deer, they chose crops that were still growing but not quite ripe. The larger one-horned rhinos were simple to spot in their favorite wheat fields as well as in lentil, rice, and mustard fields. Once they were in the field, chasing them away did not lessen the amount of damage that was done. Although male rhinos during mating season would also fight aggressors, adolescent rhinos remained largely shy and mothers with calves could be especially hostile. Rhinos appeared to cause more damage when being pursued by a group of humans with the intention of driving them back to their natural hiding places in the national park than when left alone and unmolested. This suggests a mistaken effort by neighborhood farmers that needs to be looked into more thoroughly.

The most effective deterrent, according to, was burning bundles of thatch grass carried by guards to frighten rhinos away from farms in Chitwan/Nepal after he observed several traditional techniques of doing so.

4.5.2 Mitigation strategies

In areas where greater one-horned rhino is present, crop protection measures need to be in place in the early stage of farming. At a later stage, when crops are maturing, protection measures could be lowered, but need to be enforced again during the time after harvest, when 40 crops are laid out for drying in the fields. In African wildlife areas populated by hippos, such as close to entry points at rivers (Kendall, [20]) or at hippo pools, measures for crop protection need to be taken from an early stage of growth onwards.

4.5.2.1 Electrical fencing

Many African and Asian nations have advocated the use of electric fences to keep large herbivores off agriculture and in protected areas. In order to protect crops from hippos, rhinos, and large antelopes, fencing is advised.

Although these installations might initially lessen crop loss, they have not been shown to be totally secure against any of the aforementioned species over a lengthy period of time. The management's labor- and money-intensive nature is one of the key problems.

This is particularly true during the wet season, when the grasses grow swiftly and energy is easily lost, leading to fence that is ineffectual. Furthermore, since they cannot quickly escape the barrier when pursued, the animals would suffer even greater injury.

4.5.2.2 Restoring landscapes

More room was required for breeding and habitation as the rhino population grew. All the organizations involved began rebuilding rhino habitats not only in India but also in Nepal. In order for these critters to relocate to higher ground during floods, habitat corridors were secured.

4.5.2.3 Working with locals

Human settlements surround the protected regions for larger one-horned rhinos in India and Nepal. Therefore, it was crucial for the survival of rhinos in India that the people living close to the rhino reserve have compassion for the animal. Numerous initiatives are being undertaken to protect Indian rhinos while also providing villagers with a means of subsistence by asking them to cultivate a number of particular plant species that aid in anti-poaching operations. Additionally, this lessens conflicts between people and rhinos.

4.5.2.4 Reducing unlawful trade

The concerned group is working with TRAFFIC, a network that monitors wildlife traffic, to take a number of steps to limit the illegal trade in rhino horn. To stop the illegal trafficking of rhino horns in Asian black markets, an intelligence network and anti-poaching patrols are deployed from key areas.

5. Conservation

Humans actively work to preserve wild species and their habitats through the practice of wildlife conservation. The ecological equilibrium is maintained in large part by wildlife. There are many benefits to conservation for preserving a healthy ecosystem, genetic resources, recreation, and education. The main causes of wildlife extinction include habitat loss and fragmentation, poaching, illegal trade, conflicts between people and wildlife, and pollutants. The main methods for ensuring the survival of animals include protecting vital ecosystems, wise planning and management for captive breeding, and prevention of poaching and illegal trade.

Animals, plants, and their habitats are preserved and protected through wildlife conservation. The main goals of wildlife conservation are to protect the habitat, preserve the breeding population, and outlaw the slaughter and unlawful exchange of animals [21]. Therefore, protecting wildlife has to take into account both biotic (plants, animals, and microorganisms) and abiotic (human-caused) elements. As a result, protecting wildlife resources is closely linked to protecting other natural resources.

The ecological equilibrium is maintained in large part by wildlife. Every living thing on this planet has a specific role in the food chain and makes a distinctive contribution to the ecosystem in that role. An illustration will help us to understand. When carnivores are killed, the number of herbivores increases, which in turn affects the vegetation in the forest. As a result, when there is insufficient food in the forest, the herbivores leave the forest and invade agricultural land, where they destroy the crops. When stability and balance are disturbed, numerous issues result. Unfortunately, many natural species are becoming endangered today. The main causes of wildlife extinction include habitat loss and fragmentation, poaching, illegal trade, conflicts between people and animals, and pollutants [22].

The greatest danger to wildlife is habitat degradation. There is no doubt that the extinction of wildlife species will be disastrous to this habitat. In order to maintain the conservation of wildlife and natural resources, it is imperative that we as people act responsibly.

6. Requirement for conservation

1. Balance of ecological nature

   The preservation of an ecosystem's natural equilibrium is of utmost importance. A species' population decline disrupts the natural food chain and the ecosystem, putting other species at risk. This equilibrium could be upset by the arrival of new species, the unexpected extinction of some species, natural disasters, or man-made causes. For instance, tiger and lion attacks on humans and domesticated animals occur when all the herbivorous animals in a forest are killed. In a similar manner, the killing of snakes for their skin helps the rat population to skyrocket.

2. Biological value

   Wildlife is regarded as an ecological asset and a gauge of the health of the environment. The biological value of wildlife is concerned with their role in sustaining productive ecosystems through activities including pollination, seed dissemination and planting, population management of animals and plants, nutrient recycling, and scavenging for waste [21].

3. Monetary worth

   Wildlife is abundant throughout the nation and a reliable source of income [23]. Nowadays, wildlife has grown to be a significant source of income. For commercial purposes, wildlife is harvested for its timber, firewood, hides, ivory, horns, and fur, among other products. Zoos and museums are able to keep both live and dead animals on display.

4. Educational benefit

   Numerous scientific studies and research employ wild animals. Rhesus monkeys, for instance, are frequently utilized in biomedical research.

5. Recreation

   For humans, wildlife serves as a source of entertainment and recreation. Visits to locations dedicated to animal protection are extremely beneficial to many professionals, including photographers and bird watchers.

6.1 Conservation techniques

1. Protect habitats for wildlife

   The main factor contributing to a decline in wildlife population is habitat damage. Human activity that contributes to habitat destruction includes logging, industrialization, urbanization, using forested areas for agriculture to meet human needs, and mining. Some of the natural reasons include forest fires and weather changes. One approach to safeguard our wildlife is through raising plants and saving trees, protecting the last remaining unaltered areas of natural habitat, developing new techniques to boost agricultural output without using more land, and building wildlife corridors. Since isolated populations can migrate along habitat corridors, genetic diversity is increased, and human–wildlife interactions are reduced [23]. In the forest, cultivating some flowering plants will draw insects that can aid in pollination.

2. Preventing illicit trading

   Poaching is the next biggest hazard to wild animals after habitat loss. This unlawful conduct is being carried out for a variety of absurd reasons, particularly for rare animal items like ivory, fur, organs, skin, and bones. On the other side, some animals have been hunted for food, for religious reasons, and because of some unfounded claims about their therapeutic worth. However, the truth is that there is no evidence to support the medical usefulness of animal organs 2019 [24]. Trackers that are safe and undetectable must be employed to monitor animal activity in order to stop these actions. Poaching can be dramatically decreased by outlawing the sale and purchase of wildlife animal parts in underground markets. Wild plant and animal commerce must be subject to adequate legislative and administrative controls.

3. Lowering pollution

The amount of waste produced worldwide is primarily rising daily. 5.25 trillion bits of plastic garbage are exclusively found in the oceans, according to a survey. It seriously endangers aquatic life. Other than oil spills, untreated sewage, and industrial chemicals, harmful pollutants including carbon dioxide, nitrogen dioxide, sulfur dioxide, and ozone are also produced. These pollutants have an impact on both people and animals. The endocrine system is disturbed, sex ratios vary, and reproductive parameters are diminished in animals, and teratogenic, genotoxic consequences, immunosuppression, and other immune-related illnesses are also present [25].

The efforts to be taken to lessen environmental pollution include limiting the use of plastics, recycling and reusing garbage, cleaning up the ocean, employing bacteria and some plants to break down chemical pollutants, and treating industrial wastewater to reduce pollutants. The fact that all garbage is produced by people alone means that we alone should take responsibility for keeping the environment clean.

4. Awareness

Knowledge raising awareness among those who engage in superstitious behavior, animal poisoning to protect their livestock, and poaching. Children should be taught and given the necessary training to educate others about the importance of wildlife and its management. A significant influence will be produced by educating the next generation and integrating them into wildlife conservation initiatives. Future residents' perceptions of the value of wildlife will be shaped by the inclusion of wildlife education in the school curriculum. Encouraging community involvement in wildlife management and conservation will undoubtedly enhance the status of wild species.

5. Adoption

One way to preserve the wild species held in captivity is through adoption. Many nations, including India, permit the adoption of zoo birds and wild animals. By adopting animals and feeding them on a monthly or annual basis, one can make several contributions to the conservation of wildlife. Zoos and species have different paying policies and procedures. The operation of conservation efforts, including captive breeding programs for endangered species in various zoos, will undoubtedly be aided by animal adoption programs. A person's adaptation of animals not only demonstrates his or her love for wildlife but also encourages others to do the same. The conservation of wildlife will benefit greatly from this tiny action.

6. Captivity

Animals are bred in human-controlled environments as part of the process known as captive breeding. As animal populations can grow faster than in the wild, it has been a popular management strategy for endangered species in recent years. Typically, captive breeding operations are not started until the natural population has declined to unsustainable levels [26]. In order to safeguard the population against genetic illness, captive breeding requires significantly greater attention. But it's crucial to understand that captive reproduction is insufficient to guarantee the long-term survival of endangered species.

7. Conclusion

Being a part of nature, it is natural for humans to come into contact with animals. However, because we do not fully understand animal behavior, we often feel threatened by their antics and the damage they cause to our property. We do not realize that some of our actions, even unconscious ones, may make animals feel threatened and lead to retaliation on their part. Therefore, educating the general public about such conflicts is crucial to solving the issue. If we can learn why some animals attack us and take appropriate action to stop them, we can develop positive and loving relationships with animals, which will be beneficial in the long run as we will learn how to treat them with respect and care.

There is no yet other form of mitigation, despite the fact that mitigation measures are crucial. In order to achieve the optimum results, many of the measures must be combined. Installing structures to deter birds, for instance, might be effective in the short term, but if residents continue to feed pigeons repeatedly, the problem will not be resolved. When choosing mitigation strategies, an inclusive and comprehensive approach must be used.

In the end, reducing human–wildlife conflict is a difficult endeavor since both animals and people need time to alter their habitats and behavior, therefore all the remedies must be implemented regularly over a lengthy period of time before any results can be noticed. Therefore, both residents and decision-makers must have tolerance and understanding when resolving animal conflicts.

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Section 5

Amphibian

Chapter 5

Amphibian Fauna of Manipur, North East India

Mohammad Manjur Shah, Loukrakpam Bina Chanu and Mohilal Naorem

Abstract

Manipur is one of the eight states of North-Eastern India, situated at the confluence and conjunction of two biodiversity hotspots- the Himalayan and Indo- Burma hot spots. It lies between 23°80′ N to 25°70′ N latitudes and 93°50′ E to 94°80′ E longitude, bounded by Nagaland in the North, Assam in the East, Mizoram in the south, and Myanmar in the east and southeast. Manipur has a rich diversity of culture and tradition also. The state has varied physiographic zones harboring rich and diversified amphibian fauna. We discuss the twenty-seven species of amphibian fauna reported from the region and conservation strategies and their importance in the chapter.

Keywords: amphibian, biodiversity, hotspot, Manipur

1. Introduction

Manipur has a geographical area of 22,327 km^2. It is between 23°80′ N to 25°70′ N latitudes and 93°50′ E to 94°80′ E longitude. Nagaland bounds the region in the North, Assam in the East, Mizoram in the South, and Myanmar in the East and Southeast. The state is rich in biodiversity covering under two global Bio-diversity "hotspots, "viz., Himalayan Biodiversity hotspot and Indo- Burma biodiversity hotspot. The floral and faunal diversity of the place shows affinities with the surrounding biogeographical zones. The state with many endemic species has a forest cover of 17.233 km^2 consisting of 4000 vascular plants, 430 medicinal plants, 34 edible fungi species, 500 orchid species, 55 bamboo species, 40 endemic rice cultivars, 160 fish species [1]. According to the ENVIS Hub, Manipur 2015, 13 amphibians are in Manipur. This number increased with further investigation and study. There is an excellent possibility of a further increase in the number of animals in this particular region if we could carry out a more intense and in-depth analysis of various ecosystems of Manipur.

2. Materials and methods

The present communication is a review based on the cited literature (**Figure 1**).

Amphibians are considered one of the ecosystem indicators. They live in every habitat with a rich diversity in rainforests, wetlands, deserts, alpine environments, etc.

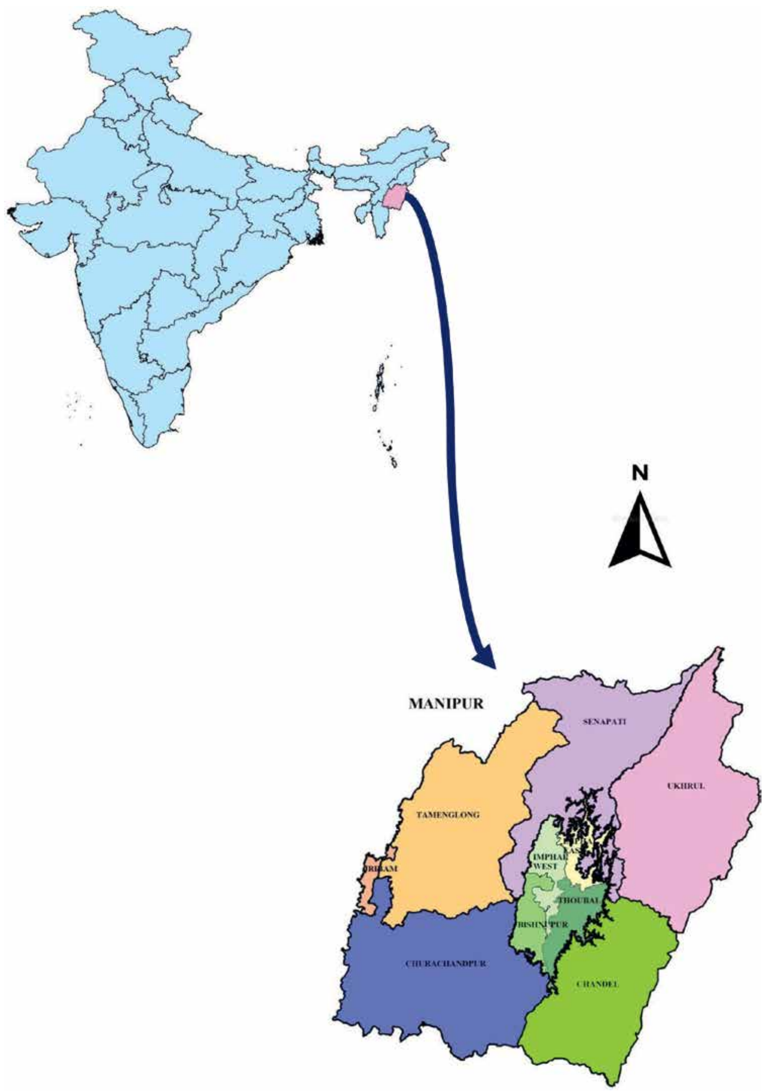

Figure 1.
Map of Manipur

The people of Manipur have loved frogs and toads from the very beginning of childhood. Sounds made by frogs and toads at night are sleep-inducing. During childhood, we played with the slippery frog eggs and alluring tadpoles at nearby ponds. Nevertheless, those croaking sounds, eggs, and tadpoles are hardly heard.

Amphibians are 4-limbed or limbless vertebrate animals which live on land and in water (amphi = dual, habit = life, i.e., dual mode of life). Amphibians evolved around 350 million years ago. They have simple body structures and delicate and permeable skin; some species have no lungs, such as salamanders. Chinese giant salamander is the largest amphibian growing up to 6 feet in length.

The class Amphibians have three orders as.

Order 1. Anura (having no tails), e.g., frogs and toads.

Order 2. Caudata (having tails and feet), e.g., newts and salamanders.


Duttaphrynus melanostictus Euphlyctis cyanophlyctis


Euphlyctis haxadactylus Fejervarya nepalensis

Fejervarya syhadrensis

Hoplobatrachus crassus

Hoplobatrachus tigerinus

Euphlyctis cyanophlyctis

Euphlyctis haxadactylus

Fejervarya terainsis

Hyla annectans

Xenophrys major

Xenophrys parva

Microhyla ornate

Amolops formosus

Amolops garbillus

Amolops marmoratus

Rana livida

Humerana humerallis

Hylarana erythraea

Hylarana tytleri

Chiromantis vittatus

Figure 2.
Photo courtesy: Wikipedia, en.wikipedia.org

Order 3. Gymnophiona (having no limbs), e.g., caecilians, *Ichthyophis*.

There are three stages of amphibians in their life cycle, i.e., Egg-Larva-Adult.

Chanda [2] reported 11 amphibian species from Manipur, Keising [3] recorded the Himalayan newt *Tylotoyriton verrucous* from Ulkhrul district, Sen and Mathew [4] listed 17 species, and Sarkar et al. [5] listed 14 species from the state (**Figure 2**).

Ningombam and Bordoloi [6] recorded the following species from Loktak lake of Manipur and its surrounding areas (**Table 1**).

3. Discussion

Frog meats are soft and can cook in many ways. They can be used for soup making, cooked curry as chicken, and dried or fried. Frogs thighs are rich in omega-3 fatty

Current family/species as per frost (2007)	Family/species as per GAA (2004)	Local name
Bufonidae	**Bufonidae**	Hangoi borabi
Duttaphrynus melanostictus (Scheider, 1799)	*Bufo melanostictus*	
Dicroglossidae	**Ranidae**	Loubuk tharoi
Euphlyctis cyanophlyctis (Schneider, 1799)	*Euphlyctis cyanophlyctis*	Pat hangoi
Euphlyctis haxadactylus (Lesson, 1834)	*Euphlyctis haxadactylus*	Narak hangoi
Fejervarya nepalensis (Dubois, 1975)	*Fejervarya nepalensis*	Narak hangoi
Fejervarya syhadrensis (Dubois, 1984)	*Fejervaryasyhadrensis*	Narak hangoi
Hoplobatrachus crassus Jerdon, 1854	*Fejervarya terainsis*	Moreh hangoi
Hoplobatrachus tigerinus Daudin, 1802	*Hoplobatrachus crassus*	Moreh hangoi
	Hopobatrachus tigerinus	
Hylidae	**Hylidae**	Hangoi
Hyla annectans (Jerdon, 1870)	*Hyla annectans*	
Megophryridae	**Megophryidae**	Keng keng pui
Xenophrys major (Boulenger, 1908)	*Xenophrys major*	Keng keng pui
Xenophrys wulianshanensis (Ye & Fei, 1995)	*Xenophrys wulianshanensis*	Keng keng pui
Xenophrys parva (Boulenger, 1893)	*Xenophrys parva*	
Microhylidae	**Microhylidae**	Hangoi
Microhyla ornata (Dumeril & Bibron, 1841)	*Microhyla ornate*	
Ranidae	**Ranidae**	Keng keng pui
Amolops formosus (Gunther, 1876)	*Amolops formosus*	Keng keng pui
Amolops gerbillus (Annandale, 1912)	*Amolops gerbillus*	Keng keng pui
Amolops marmoratus (Blyth, 1856)	*Amolops marmoratus*	Hangoi
Hula livida (Blyth, 1855)	*Rana livida*	Hangoi
Humerana humerallis (Boulenger, 1887)	*Rana humeralis*	Hangoi
Hylarana erythraea (Schiegel, 1837)	*Rana erythraea*	Hangoi
Hylarana tytleri (Theobald, 1868)	*Rana tytleri*	
Rhacophoridae	**Racophoridae**	Hangoi
Chiromantis vittatus (Boulenger, 1887)	**Ranidae/***Chirixalus vittatus*	Hangoi tansang
Polypedates megacephalus Hallowell, 1861	*Polypedates megacephalus*	Hangoi tangsang
Polypedates leucomystax (Gravenhorst, 1829)	*Polypedates teraiensis*	Hangoi
*Rhacophorus bipunctat*us Ahl, 1927	*Rhacophorus bipunctatus*	Hangoi
Rhacophorus maximus Gunther, 1858	*Rhacophorus maximus*	

Table 1.
Checklist of the amphibians reported from Manipur, north-East India.

acids, potassium, and vitamin A. some tribal people in the hills, as well as people in the plains of Manipur, eat dried amphibians. Frogs are dried in the sun or heat and sold in markets like smoked fish. Fermented dried frogs are also available. The fermented frogs could also be converted into chatni and sold in the markets of some hill districts of Manipur [7].

In Manipur, Loktak Lake provides the congenital breeding ground for the different species of frogs. The frogs recorded so far belong to the lotic and the lentic ecosystem. *Xenophrys wuliangshanensis*, *Xenophrys major*, *X. parva*, *Amolops formossus*, *Anolopsgerbillus*, *Humerana humeralis*, *Euphlyetis heradactylus* were reported from the Border States like Nagaland and Arunachal Pradesh [1, 8].

Frogs have essential roles as predators and prey in the food chain. Young tadpoles and adult frogs eat algae and regulate the algal blooms reducing algal contamination. Birds, fish, monkeys, and snakes prey on frogs. If frogs disappear, there will be deterioration in the food web throughout an entire ecosystem. They have highly permeable skin that can easily absorb bacteria, chemicals, and other toxins, which makes them susceptible to the environment and considered environmental indicators. Frogs eat pesky bugs, adults, and larvae of mosquitoes that can transmit dengue fever, malaria, WEST Nile fever, and Zika. They have been a model for various biological processes in laboratory studies. Frogs' toxins have are potential as therapeutic drugs.

4. Conservation of amphibians

Amphibians play crucial roles as predators and prey, helping maintain the balance of nature. They also act as bioindicators that help us monitor the health of the ecosystems. They are also cultural and religious symbols such as rain, life, and good luck.

There are myriad benefits from amphibians. Major ones include:

- Basic science: amphibians can yield many secrets through basic scientific research

- Ecosystem health: they help in the maintenance of ecosystem health

- Bioindicators: they can act as bioindicators of ecosystem health

- Medicines: many of them give beautiful medicines, e.g., the Australian red-eyed tree frog (*Litoria chloris*) produces an anti-AIDS compound

- Biocontrol: as they eat insects, they help check agricultural insect pests and diseases such as malaria

- Esthetic: they are beautiful animals and have the right to exist

- Cultural: amphibians are cultural symbols used as harbingers of rain, good luck, and happy life.

Due to global warming or a temperature rise, there may be some effect on the population and reproduction of these dual-life amphibians. Besides these, many amphibian eaters in Manipur consider them a portion of traditional food. Food is scarce due to overpopulation's decrease in the cultivable land area resulted by overpopulation. There is malnutrition in poverty-line children, especially in Manipur [4]. Manipur has high endemicity. Nevertheless, climate change and anthropogenic pressures such as the destruction of habitat, heavy urbanization, and the destruction of wetlands have led to the extinction of amphibians from North-East India. With the help of various National and International legislations, there is an urgent need to conserve and maintain the amphibian population.

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Section 6

Fungi and Oomycetes

Chapter 6

Fungi and Oomycetes–Allies in Eliminating Environmental Pathogens

Iasmina Luca

Abstract

Fungi and oomycetes are the subjects of numerous current research studies. These are natural agents that can control parasitic populations, and arthropod populations with a role in the transmission of various diseases but can also eliminate various pollutants that are found in the external environment. Therefore, their conservation and exploitation are a global necessity, due to the benefits they confer on the quality of life of animals, but also of humans. Science must be aimed at finding a balance between the different constituents of the ecosystem and establishing coexistence relationships that are beneficial to all. Thus, research should be directed at investigating the potential actions of fungi and oomycetes against the various agents with which they coexist naturally in the external environment. This chapter provides information regarding the mechanism of action of these natural constituents and updates information on the species of fungi and oomycetes that have been studied so far. Thus, readers can have a base in this field and can further exploit what they have discovered to continue to improve the welfare of animals, addressing an ecological and healthy vision.

Keywords: ecological action, fungi, oomycetes, cleaning

1. Introduction

Plants and animals coexist in a certain balance within the ecosystem, together with fungi, oomycetes, bacteria, viruses, and parasites.

Currently, about 75.000 species of fungi have been described, many of which are still unclassified [1]. Also, in the category of fungi, oomycetes have been included in the past. Detailed studies have highlighted their morphological and functional differences, the oomycetes being now included in the phylum *Oomycota* [2]. Both fungi and oomycetes are found in various symbiotic relationships and can be saprophytes or parasites [3]. These relationships can be exploited in creating ideal habitats for animals.

Many bacteria, viruses, and single-celled parasites can be carried by arthropods (insects, mites) or other vectors (amoebas) and can be sources of infection, causing many diseases in animals. Fungi and oomycetes can use different mechanisms by which they can eliminate these vectors. They can also be involved in the detoxification of the environment from numerous pollutants and can be considered important agents in the biocontrol of some animal parasites. In removing amoebae, fungi use hyphae that function as "sticky extensions" that capture "prey" or can parasitize internally, causing amoebae death by sporulation [4]. Sprayed in the form of a solution on the body of insects, more precisely on the body of mosquitoes, the fungi attach themselves through the conidia to their cuticle. Then begins the germination and dispersal of spores in the hemocoel. At this level, the evolutionary cycle of fungi continues with the multiplication of hyphae, which gradually kill the host by colonizing the trachea and producing toxins, after which the fungi leave their body [5, 6]. In eliminating the larval forms of some insects, the fungi also through the conidia block the siphon region and thus determine the death by asphyxiation of the hosts [6]. The same mechanisms have been reported in the elimination of evolutionary stages of ticks. An important role in the fixation and adhesion of conidia at the cuticular level is played by hydrophobins and adhesins, as proteins, but also lipase and esterase, as enzymes [7–9].

Certain pollutants, such as pesticides, can be battered by various fungi through numerous chemical processes (deoxygenation, hydroxylation, esterification, or dehydrogenation) [10]. Certain heavy metals in the environment can be inactivated by organic acids and siderophores (metabolites) of fungi [11]. Enzymes also play an important role in bioremediation, among them can be mentioned: cellulase, lipase, protease, peroxidase, amylase, chitinase, catalase, laccase, xylanase, etc. [12].

In the management of parasitic populations, especially nematode populations found in animals, fungi use complex mechanisms to eliminate these pathogens. The first stage is the recognition between the fungus and the nematode. Fungi adhere to the body of nematodes through lecithin that binds to carbohydrate receptors located in the cuticle of the parasite [13, 14]. Adhesion is facilitated by fungal spores and protein fibrils that form nematode-trapping traps. The fibrils are arranged in a network or perpendicular to the external surface of the nematodes, after which they easily penetrate their body. The penetration step involves the release of hydrolytic enzymes and the application of progressive pressure on the parasite's cuticle [15]. After complete penetration of the cuticle, the formation and multiplication of hyphae begin. Gradually the fungi digest the nematodes internally. Nutrients are captured in the hyphae in lipid droplets or are fixed and carried by lecithin [16]. The same steps are observed in the case of oomycetes. They adhere to the surface of parasite eggs or larvae, through hyphae, after which they penetrate the egg wall or larval cuticle, releasing various enzymes (various exoglycosidases, kinases, endo-β-1,3-glucanases, and cellulases). Gradually, they digest and destroy the internal contents through hyphae and zoospores that form continuously [17].

Another method of removing nematodes is using adhesive nets, hyphae, or knobs forming constricting rings together. Through the movements and body heat, the nematodes trigger the complete tightening of the rings around them and the exteriorization of a penetrating tube where the internal multiplication of the hyphae begins [18]. Certain fungi can spread to the surface of the body of nematodes or larvae, including the wall of nematode eggs. Gradually the sporulation takes place internally, having an ovicidal, larvicidal, or adulticidal effect [19, 20]. An ovicidal effect can be exerted by fungi also through hyphae, more precisely through oppressors, secondary metabolites, and the toxins they contain [19]. The same toxins can cause paralysis of adult nematodes [19].

The following subchapters contain information related to fungal species, but also oomycetes that can be used successfully in the elimination of various animal pathogens.

2. Elimination of vectors involved in the transmission of various diseases to animals

2.1 Amoebae

Amoebae are protozoa that can live freely in very different environments or can be parasitic, surviving in different hosts. Free amoebae are present in the external environment in soil, water, and air, but are also used in various medical fields, such as dialysis centers and dentistry [21]. Parasitic amoebae (*Entamoeba* spp. and *Balantidium* spp.) are found in animals' intestines [22].

In veterinary medicine, only four classes of free amoebae have pathogenic potential: *Acanthamoeba*, *Naegleria*, *Balamuthia,* and *Sappinia* [23]. Each class determines certain clinical manifestations of amoebiasis. *Acanthamoeba* enters the animal body by respiration or skin and through the circulation reaches the central nervous system, causing amoebic granulomatous encephalitis (GAE) [21, 24, 25]. The evolution of the disease is slow, and long-lasting [26]. Certain species of the genus *Balamuthia* (*Balamuthia mandrillaris*) cause similar lesions, respectively: granulomatous *Balamuthia encephalitis* (BAE) [27]. The route of infection is predominantly cutaneous [28]. *Sappiniae* amoebic encephalitis (SAE) is caused by two species, *Sappinia diploidea* and *Sappinia pedata* [29]. From the *Naegleria* class, *Naegleria fowleri* is important. It is found in water and can be accidentally inhaled by animals while swimming [30]. The location is also in the brain, but the migration route is a nerve (olfactory nerve pathway) [18]. The characteristic lesion caused by this class of amoebas is meningoencephalitis, which develops with diffuse cerebral edema [30].

An important role in the circulation of certain pathogens has the amoebas of the *Acanthamoeba* class. Among the pathogens are bacteria (*Listeria monocytogenes*, *Pseudomonas aeruginosa*, *Rickettsia*-like, *Salmonella enterica*, *S. thyphimurium*, *Yersinia enterocolitica*, *Campylobacter jejuni*, *M. avium*, *M. bovis*, *Bacillus anthracis*, *Escherichia coli* O157, *Helicobacter pylori*, *Chlamydia pneumoniae*, *Coxiella burnetii*, *Francisella tularensis*) [31–42], fungi (*Cryptosporidium parvum*, *Cryptococcus neoformans*) [43–45] and a limited number of viruses (*Adenoviridae*) [46].

Numerous researchers aim to use amoebophagous fungi in the elimination of vectors and in the prevention of many diseases that can be transmitted to animals. They can act as parasites or predators. Among the fungi with the role of parasites, which invade and multiply inside the amoebae, are found *C. neoformans*, *Blastomyces dermatitidis*, *Sporothrix schenckii*, *Histoplasma capsulatum*, *Aspergillus* spp., *Penicillium* spp. and *Fusarium* spp. [23, 43, 47–50]. There are species of fungi that multiply in the nucleus (*Nucleophaga* sp.) [51] or others that multiply in the cytoplasm of amoebas (*Sphaerita*, *Pseudosphaerita*) [4]. Species such as *Paramicrosporidium* can cause degeneration and changes in the nuclear and plasma membranes of amoebae [52, 53]. Amoeba trophozoites can be parasitized by *Cochlonema* species [54–57] or can be captured by hyphae of fungi, such as *Stylopage* [58] and *Acaulopage* [59, 60]. Mycotoxins produced by fungi also have a role in the degeneration and decomposition of trophozoite or cyst forms of amoebae [61]. Thus, ameobophagous fungi can be used in the elimination of pathogens carried by amoebae, by applying and cultivating them in soils and waters.

2.2 Insects

Globally, insects can be found in many habitats [62]. They have an important role in all terrestrial ecosystems, intervening in soil fertilization by circulating nutrients and seeds, but also in plant pollination. Thus, they are essential for maintaining optimal qualities in the development of agriculture [63]. Another role with a major impact on the quality of life of animals is the fact that insects are a nutritional basis for them [64]. The larval and adult stages are the most frequently consumed by animals.

In veterinary medicine, the role of insects is very important. Like amoebae, they can transmit various diseases from one animal to another. *Diptera*, insects, flies, and mosquitoes have a major impact on animal health. Culicoids can carry viruses such as BTV (bluetongue virus), AHSV (African horse sickness virus), EHDV (Epizootic hemorrhagic disease virus), and Akabane virus [65]. Newcastle disease [66], certain bacterial agents (*E. coli*, *Salmonella*, *Shigella* spp., *S. aureus*, *Campylobacter*) and parasites (*E. vermicularis*, *S. stercoralis*, *T. canis*, *Trichomona*s, *Diphyllobothrium*, *Taenia*, *Dipylidium*, *Entamoeba histolytica*, *Giardia lamblia*) can be mechanically carried by flies, especially the domestic fly [67–69]. Mosquitoes, in turn, can carry many pathogens, such as West Nile virus, Rift Valley fever virus, Wesselsbron virus, Middelburg virus, Israel Turkey encephalitis virus, Usutu virus, Batai virus, Sindbis virus, Japanese encephalitis virus, St. Louis encephalitis virus, Eastern equine encephalitis virus, Western equine encephalitis virus, Venezuelan equine encephalitis virus, Tembusu virus, *Wuchereria bancrofti*, *Plasmodium relictum* (avian malaria), *T. corvi* (avian trypanosomiasis), *Chandlerella quiscali* (avian filarial worms), *Dirofilaria repens* and *Dirofilaria immitis* [70–79].

The use of pyrethroids as insecticides is the most widely used method of control. However, recent research aims to apply fungi, in various forms, as an ecological method of controlling insect populations [80]. Ansari et al. [81] used the conidia of several species of fungi against culicid adults. The species chosen were *Metarhizium anisopliae* V275, *Isaria fumosorosea* PFR 97, *Isaria fumosorosea* CLO 55, *Beauveria bassiana* BG and *Lecanicillium longisporum*. Conidia were applied in the form of dry conidia and wet conidia, the first variant being the most effective, causing the death of all individuals after 5 days. The most virulent strain of the fungus was *Metarhizium anisopliae* V275 [81]. The same fungus was effective against larval forms of culicids, houseflies, horn flies, and mosquitoes [82–86]. Other authors have reported a larvicidal potential of *Culicinomyces clavisporus* against culicids [87]. Fly larvae, mosquitoes, and culicids have also been eliminated by *Beauveria bassiana*, with many studies reporting this [83–86]. This fungus has led to the death of culicid larvae of the species *Culex tarsalis*, *Culex pipiens*, *Anopheles albimanus*, *Ochlerotatus sierrensis*, *Ochlerotatus nigromaculis,* and *Aedes aegypti* [88]. Ong'wen et al. [89] tested the simultaneous action of dragonfly nymphs *Pantala favescens* and *B. bassiana* spores against *Anopheles gambiae* mosquitoes. They observed that the larvae exposed to the action of nymphs (predatory role) were much more vulnerable, in the adult stage, to the action of *B. bassiana* spores [89]. Ishii et al. [90] demonstrated the adulticidal action of *B. bassiana* conidia against *An. stephensi* mosquitoes. Seven days after exposure, the insect's body was completely invaded by hyphae [90]. Oomycetes *Lagenidium giganteum*, *Aphanomyces laevis*, *Couchia* spp., *Crypticola* spp., *Leptolegnia caudata* and *Pythium* spp. can kill mosquito larvae through mycelium and oospores [91, 92].

2.3 Ticks

Ticks are parasitic mites, which require, for the complete development and completion of the biological cycle, a blood-feed on the vertebrates involved. The tick population is extremely numerous in the warm season, being an important agent for transmitting contagious diseases to animals, but also humans. They can carry bacteria (*Borrelia*, *Ehrlichia*, *Anaplasma*, *Coxiella*, *Brucella*, *Francisella tulacobacteria*, *Rickettsia* spp.) [93–95], piroplasmas (*Babesia*, *Theileria*), but also protozoa (*Cytauxzoon*, *Hepatozoon*) [76].

Biological control of ticks can be achieved by using entomopathogenic fungi. Currently, many fungi are known with a high potential to eliminate various evolutionary forms of ticks. Among them are: *Beauveria bassiana*, *Beauveria brognardi*, *Metarhizium anisopliae*, *Metarhizium robertsii*, *Metarhizium brunneum*, *Fusarium* sp., *Aspergillus fumigatus*, *Aspergillus ochraceus*, *Aspergillus flavus*, *Aspergillus niger*, *Aspergillus parasiticus*, *Isaria fumosorosea*, *Scopulariopsis brevicaulis*, *Paecilomyces lilacinus*, *Paecilomyces farinosus*, *Paecilomyces fumosoroseus*, *Penicillium insectivorum*, *Conidiobolus coronatus*, *Trichothecium roseum*, *Verticillium aranearum*, *Verticillium lecanii*, *Isaria fumosorosea*, *Isaria farinose*, *Curvularia lunata*, *Rhizopus thailandensis*, and *Rhizopus arrhizus* [96–114].

Depending on the evolutionary stage, the action of certain fungi is different. Eggs are the most sensitive and nymphs are the most resistant [115, 116]. A high ovicidal action against *Boophilus microplus* eggs were observed in *Verticillium lecanii* (strains LBV-2 and LBV-1) and lower in *Beauveria bassiana* [117]. A decrease in hatching capacity and indirectly the number of larvae formed have been reported by some authors regarding the action of *I. fumosorosea* [112]. The same effect was indicated for *Isaria farinosa* and *Purpureocillium lilacinum* [112]. *Metarhizium anisopliae* Ma-z4 has larvicidal action on the same species of ticks mentioned above [118]. In the case of adult females of *B. microplus*, the isolates E9 and AM of *Metarhizium anisopliae*, applied to the body of animals through spores in a concentration of 7.5×10^8 conidia/ml, determined high mortality and negatively influenced the number of eggs laid by females [119]. A pronounced acaricidal effect on adult females of *Dermanyssus gallinae* was noted in *B. bassiana* CD1123 conidia, applied at a concentration of 10^9/ml [120]. An ovicidal, larvicidal, and adulticidal effect against *Argas reflexus* ticks has been reported in V245, 685, and 715C of *Metarhizium anisopliae*, the first strain being the most pathogenic [121]. High mortality, observed starting one week after application, was also recorded in females of *Rhipicephalus annulatus* exposed to the action of *Metarhizium anisopliae* [122].

Varroa destructor mites are important in veterinary medicine as a consequence of the devastating effects induced in bee populations. Honey is an intense natural product used in various diseases in animals. It helps to heal wounds [123, 124], to treat gastric ulcers, and can be used as an adjunct in the treatment of diabetes, certain bacterial or parasitic infections, and in stopping the growth of tumors [125]. So, protecting bees is undoubtedly fundamental. The scientific research has brought favorable results regarding the use of the following fungi against *V. destructor* mites: *Beauveria bassiana*, *Hirsutella* spp., *Metarhizium* spp., *Paecilomyces* spp., *Tolypocladium* spp., *Verticillium lecanii*, *Clonostachys rosea* and *Lecanicillium lecanii* [126–133].

3. Environmental detoxification

Currently, our planet is going through continuous degradation due to the numerous pollutants accumulated in soils, waters, and air. Many of them are difficult to decompose. The current trend in research concerns the concept of bioremediation. It refers to the use of certain microbes in various habitats to metabolize various pollutants [134, 135]. Fungi have been intensively studied, their potential to cleanse the planet being recognized by many researchers. Detoxified soils are more fertile, ensuring rapid growth of plants, their nutritional qualities being better preserved. Indirectly, fungi provide animals with adequate food. The same is true of detoxifying water and air: it improves the quality of life of animals.

3.1 Heavy metals in the soil

Animals exposed for a long time to the action of heavy metals have developed developmental problems, spermatogenesis, neurological, renal, and liver problems [136]. Their carcinogenic potential has also been reported [137].

The action of fungi on heavy metals in the soil (Pb, Cd, Cu, Zn, Cr, Ni, Ag) is mediated by external temperature, but also by pH, the whole detoxification process being explained by the phenomena of bioabsorption, bioconcentration, and biotransformation [138]. Among the effective fungi are *Beauveria bassiana*, *Aspergillus* sp., *Fusarium* sp., *Penicillium chrysogenum*, *Rhizopus* sp., and *Absidia* [139–143].

3.2 Pesticides in wastewater

Wastewater is subject to filtration and treatment, as it can be an important source of pesticides, with harmful effects on the environment and animals. Currently, certain fungi capable of eliminating these pollutants have been identified. Hultberg and Bodin [144] used experimentally a combination of *Chlorella vulgaris* (algae) and *Aspergillus niger* and observed a significant reduction in the concentration of pesticides present in water. Piazides based on triazines, dicarboximides, and organophosphates can be successfully degraded by *Verticillium* sp. (H5) and *Metacordyceps* sp. (H12) [145].

Certain residual insecticides, such as endosulfan, can be deteriorated by *Penicillium chrysogenum*, *Bacillus subtilis*, *Aspergillus terreus*, *Aspergillus flavus*, *Aspergillus niger*, *Fusarium ventricosum,* and *Cladosporium oxysporum* [146–148]. Mohammed and Badawy [149] indicate the use of *A. terreus* YESM3 in the elimination of the insecticide imidacloprid.

3.3 Various pollutants from soil, water, and air

Xenobiotic compounds are chemicals that enter the animal body in numerous ways (digestive, respiratory, parenteral) and are various. Reproductive problems (infertility, abortion) have been reported in animals following exposure [150]. Many plant constituents, various pesticides, medicinal products, feed additives, or industrial chemicals, are considered xenobiotics [151]. They have been successfully degraded by species of white-rot fungi (*Pleurotus* spp., *Agaricus bisporus*, *Bjerkandera adusta*, *Phanerochaete chrysosporium*, *Irpex lacteus*, *Lentinula edodes*, *Trametes versicolor*) [152].

Polycyclic aromatic hydrocarbons are found in the form of aerosol particles and can enter the body through the respiratory tract. Prolonged exposure to these constituents has devastating effects on the body. They can adversely affect the endocrine, reproductive, immune, and nervous systems. It also has a carcinogenic and teratogenic action [153]. *Polyporus* sp. S133, *Hypocrea,* and *Fusarium* can decompose polycyclic aromatic hydrocarbons [10]. Recent studies show that the *Pythium aphanidermatum* oomycete intensifies the action of *Mycobacterium gilvum* VM552 and *Pseudomonas putida* G7 against the pollutants mentioned [154].

4. Biocontrol of animal parasitosis

Parasites are pathogens that can survive in the body of animals for long periods, significantly affecting their quality of life. Depending on the class they belong to (Protozoa, Trematodes, Cestodes, Nematodes), they can be diagnosed in different age categories of the hosts [155]. There are many ways to infest animals, with a major impact on the digestive tract. In this way, the hosts can ingest from the external environment eggs or larvae of parasites. Adult forms usually survive in various animal organs. In stopping the evolutionary cycle of parasites, the veterinarian must take several preventive measures. These are undoubtedly necessary, due to the zoonotic potential of certain parasites. To eliminate and kill the adult forms, but also certain larval stages of the parasites, it is well known that various medicinal substances with the antiparasitic role are used. Of the four parasitic classes, nematodes are the most developed, and the main classes of drugs used against them are benzimidazoles, nicotinic receptor agonists, and macrocyclic lactones (avermectins, milbemycins) [156]. Cestodes are sensitive to isoquinolines (praziquantel) and trematodes to thiabendazole (benzimidazole) [157]. We mention only the helminths because they are pentiful in the animal population and the intermediate evolutionary forms resist the most in the external environment. One aspect that must be taken into account when administering the anthelmintics mentioned above is the one related to their use in farm animals. The possibility of eliminating them through milk (ruminants) must be known and indirectly, their remanence in certain secondary products must be mentioned. Macrocyclic lactones also have a long residue in the body of animals [158]. Analyzing this desideratum we can consider the elimination and the complete degradation of parasitic elements from the external environment as the main stage in stopping the biological cycle of parasites. This stage was a basis for current research in the field of biomedical sciences. Disinfectants have been tested and analyzed in numerous studies. Among those discovered so far as having a potential effect on the intermediate elements of nematodes, are those based on alcohols (ethanol, propanol), pentapotassium, and quaternary ammonium compounds [159, 160]. Alcohol-based disinfectants and more can have a corrosive effect if applied to different surfaces and instruments. Also, not enough details are known about the effect they can have on the skin of animals. Here we refer to those kept in paddocks or cages. Considering these aspects, the current research investigates the application of some fungi or oomycetes in the control of the evolutionary cycle of parasites, being an ecological and environmentally friendly method.

Ruminants are frequently parasitized with trichostrongyls. Of these, *Haemonchus* sp. is very important due to the severe anemias, but also to the elaborate clinical symptoms that it can give. Many studies have reported the nematicidal action of some *Pleurotus* species against larval forms (L1, L3, L4), but also of adult *Haemonchus* sp. [161]. This action is due to chemical compounds contained in hyphae (fatty acids, alkaloids, quinones, peptides, polyphenols, and terpenoids) [162]. Vieira et al. [163] associated two fungi (*Pochonia chlamydosporia* VC4 isolate and *Arthrobotrys cladodes* var. macroides CG719 isolate) against the larvae of *Haemonchus* sp. but also of *Cooperia* sp. and *Oesophagostomum* sp. The results were promising, the two fungi potentiating each other's action [163]. Besides the larvicidal action, *P. chlamydosporia* also has an ovicidal action against some helminth eggs [164]. Other researchers have observed that *A. cladodes* used alone against the larvae of *Haemonchus* sp. resulted in high mortality, between 68.7% and 81.73% [165–167]. Silva et al. [168] do not recommend the associations between the following fungi, in combating the larval forms of *Haemonchus* sp.: *Duddingtonia flagrans*, *Clonostachys rosea*, *Arthrobotrys musiformis,* and *Trichoderma esau*. Other authors propose the use of the following fungi, frequently isolated from the external environment, in the control of gastro-intestinal helminthiases of small ruminants: *Arthrobotrys oligospora*, *Candelabrella musiformis*, *Arundo conoides*, *Andropogon dactyloides*, *Trichoderma*, *Beauveria*, *Clonostachys* and *Lecanicillium* [169]. Cai et al. [170] investigated the action of two species of *Arthrobotrys* (*Arthrobotrys musiformis* and *Arthrobotrys robusta*) against the larval forms of trichostrongyls from sheep and goats. The percentages obtained were remarkable, between 97.71% and 99.98% [170]. Similar results regarding the larvicidal action of *Arthrobotrys musiformis* (90.4%) were reported by Silva et al. [171] and much lower percentages of 50% were obtained by Acevedo-Ramírez et al. [172]. The same authors observed a reduction in the number of *Haemonchus* sp. larvae, over 60% in the case of *Trichoderma esau* and *Clonostachys rosea* and 85.7% in the case of *Duddingtonia flagrans* [171]. A larval reduction of over 90% was identified by Chandrawathani et al. after administering *in vivo* to small ruminants *D. flagrans* at a dose of 1×10^6 spores/animal/day for 6 days [173].

Other researchers have investigated the action of fungi (*Arthrobotrys* sp. E1; *A. cladodes* CG719; *A. conoides* I40; *A. musiformis* A1, A2, A3; *A. oligospora* C1, C2; *A. robusta* B1, I31; *Duddingtonia flagrans* CG722, CG768; *Monacrosporium appendiculatum* CGI; *Methanocorpusculum sinense* SF53, SF139; *M. thaumasium* NF34A; *Nematoctonus robustus* D1) on infesting larvae of *Strongyloides papillosus* isolated from cattle. The results were satisfactory, causing a larval reduction between 65.4 and 100% [174]. *D. flagrans* can destroy *Strongyloides* larvae in 2 weeks, and *V. chlamidosporium* (PTCC 5179) in 3 weeks, as reported by Zarrin et al. [175]. The same authors indicate the use of *F. solani* (PTCC 5284) and *T. harzianum* (IBRC-M 30059) in the control of strongyloidiasis in domestic animals [175].

In horses, Araujo et al. [176] investigated the larvicidal action of 3 fungi (*Duddingtonia flagrans* AC001, *Monacrosporium thaumasium* NF34, *Arthrobotrys robusta* I-31) against *Strongyloides westeri*. The results showed a reduction in the larval population between 67.9% and 80.4% [176]. Also in horses, effective against the larvae of *Strongylus equinus*, it is *Arthrobotrys oligospora* [177]. *P. chlamydosporia* is a fungus used in numerous researches against several species of parasites, against which it has shown significant negative effects. Among the species of parasites that have proved sensitive to its action, are found: *Ascaridia galli* [178, 179], *Heterakis gallinarum* [178, 179], *Oxyuris equi* [180], *Ascaris suum* [181], and *Toxocara canis* [182].

A satisfactory larvicidal potential against the gastrointestinal nematode *Ancylostoma caninum*, found in canids, had the fungus *Arthrobotrys oligospora* [177] and the oomycete *Pythium oligandrum* [183]. The same oomycete has an ovicidal action against *Toxocara canis* and *Toxocara cati* eggs, found in dogs and cats [17]. Other authors recommend the use of *Paecilomyces lilacinus*, *Trichoderma virens,* and *Fusarium pallidoroseum* in the biocontrol of ascariasis in dogs [184–186].

Biocontrol in animal trematodes is still at the beginning of the research, until now the ovicidal effect of *Paecilomyces lilacinus* and *P. variety* against *Fasciola gigantica* [187], but also *P. chlamydosporia* against *Fasciola hepatica* eggs [188] are known.

5. Conclusions

Fungi and oomycetes are important agents in the control of animal diseases, which can seriously alter their health. Through the actions they present (insecticide, amoebicide, antiparasitic - ovicidal, larvicidal, nematicidal, and anti-pollution) according to those deduced from the scientific literature, they are key elements in ensuring the welfare of animals and improving their quality of life.

Conflict of interest

There are no conflicts of interest to declare.

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Section 7

Cattle

Chapter 7

Aiming to Improve Dairy Cattle Welfare by Using Precision Technology to Track Lameness, Mastitis, Somatic Cell Count and Body Condition Score

Dinesh Chandra Rai and Vinod Bhateshwar

Abstract

Specific animal-based indicators that may be used to predict animal welfare have been at the basis of techniques for monitoring farm animal welfare, such as those developed by the Welfare Quality project. In addition, the use of technical instruments to accurately and immediately measure farm animal welfare is obvious. Precision livestock farming (PLF) has enhanced production, economic viability, and animal welfare in dairy farms by using technology instruments. Despite the fact that PLF was only recently adopted, the need for technical assistance on farms is getting more and more attention and has resulted in substantial scientific contributions in a wide range of fields within the dairy sector, with a focus on the health and welfare of cows. Among the most important animal-based indicators of dairy cow welfare are lameness, mastitis, somatic cell count and body condition, and this chapter aims to highlight the most recent advances in PLF in this area. Finally, a discussion is presented on the possibility of integrating the information obtained by PLF into a welfare assessment framework.

Keywords: animal welfare, behaviour, body condition score, dairy cattle, infrared thermography, lameness, mastitis, precision livestock farming, somatic cell count

1. Introduction

Animal welfare with several legislative initiatives from the late 1980s to the present day has long been considered a high priority within the European Union (EU) [1]. In addition, as part of a policy-oriented strategy to find methods to enhance animals' lives, the EU has made major investments in research into the welfare of farm animals [2, 3]. For the improving the standard of animal welfare the important part is an animal observation. In this regard, attempts have been undertaken to investigate science-based welfare indicators as assessment methods [4, 5]. For example, the Welfare Quality® project contributed with protocols to assess animal welfare in

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cattle, pigs, and poultry [6, 7]. A few years later, the AWIN® project developed indicators for animals not included in Welfare Quality®, including horses, donkeys, turkeys, sheep, and goats [8]. However, there are several practical problems in implementing these protocols, preventing them from having the greatest influence on farm animals' quality of life [9–11]. However, the advancements made in precision livestock farming (PLF) during the past 20 years, with strong cooperation between engineering and livestock sector experts, have led to a considerable change in how animal welfare is assessed. PLF has developed rapidly in recent years, and animal welfare can be objectively assessed in real-time using a wide variety of indicators [12]. This analysis of welfare indicators is already achievable, and it is anticipated to make significant advancements for cattle production in the near future. Applying the most recent advancements in information, communication, and sensor technologies will be necessary to achieve this [13]. Through data from image, sound, and movement sensors coupled with algorithms, it is possible to monitor the welfare of cows, their production, and management techniques [14, 15]. At the moment, there is strong evidence pointing to the feasibility of automatically monitoring and evaluating welfare with outputs that can be included into welfare protocols [12, 16, 17]. Furthermore, a suitable data presentation is required so that farmers embrace and use the technology in PLF solutions effectively [18]. This chapter will examine PLF current work in assessing lameness, mastitis, and body condition, all of which are considered welfare indicators for dairy cows. This chapter also aimed to identify future opportunities for PLF solutions, such as automatically incorporating animal-based indicators into a dairy farm welfare framework, enabling for the establishment of superior welfare for the animals and value for the farmer.

2. Welfare of dairy cows and precision livestock farming

There are presently three methods for evaluating the welfare of dairy cattle, farmers ensuring responsible management in USA [19], the code in New Zealand [20], and welfare quality in Europe [21]. The latter approach has received significant criticism in a number of studies [22–24], which offered a number of recommendations for lowering the number of assessed parameters to get around the time-consuming observations, which is a limitation that prevents its normal deployment in dairy farms. Along with limiting the assessment processes, the scoring methodology was also altered and made more flexible so that measures may be modified or added as considered appropriate [23]. According to Krueger et al. [25], another welfare evaluation system under development is the integrated diagnostic welfare system (IDWS). Because it uses technology to assist farms in evaluating animal welfare and identifying any reasons of poor welfare, this method may alleviate some of the problems of the other three systems. However, a significant quantity of data and records are required to document animal behaviour, health, and welfare conditions; and the use of sensors and technology can assist in this situation (**Figure 1**) [26]. According to Knight [27], study on dairy cattle sensors has been very dynamic for detecting lameness, mastitis, and body condition, which will be the target of this work. Moreover, sensors are being used for a wide range of different purposes, including fertility (e.g., oestrus cycle and parturition), nutrition, health, and general management of dairy animals. As a result, the primary monitoring systems in dairy farms give complete information in several areas and demonstrate their appropriateness and practicality for dairy farm implementation [26].

Figure 1.
Collars in dairy cows provide relevant data, save time, and give proper needed information.

2.1 Lameness

After mastitis and reproductive problems, lameness is the third leading cause of economic losses on dairy farms. Mastitis, metabolic problems, and decreased fertility are more common in lame cows [28]. Lameness in dairy cows can vary significantly in incidence and can appear weeks or even months after a metabolic disorder, making it difficult to determine the cause of the lameness [29]. Lameness is typically diagnosed at an advanced stage of the disease, when it is most seriously and expensively treated. An animal in such conditions may require several weeks to recover, costing dairy farmers a lot of time and money in the form of calls to the veterinarian, medication, and therapeutic interventions [30]. The dairy farmer's time constraints are one element that contributes to the under-detection of lameness issues. Therefore, behaviour of the cows must thus be recorded using flexible and reasonably priced sensor-based devices in order to detect the beginning of lameness [31]. Treatment and prevention are important parts of lameness management. Improvements in walking surfaces, diet, and genetics are only a few of the factors that are connected to lameness and may be managed through prevention. The farmer must first identify a cow as lame before treating it. There are typically three ways that this occurs. The first is performing a systematic evaluation of the herd using a locomotion scoring system [32]. The second is regular trimming of the hoofs. Legs are lifted here to be examined and, if necessary, treated [33]. The third and most typical method is casual observation while performing other operations, including herding. Unfortunately, mild and even moderate lameness cannot be detected through ad hoc detection. Automated lameness identification has the potential to fill in information gaps regarding the cow and herd, for cows that are mildly to moderately lame. The period from the onset of lameness to treatment might be shortened with earlier detection and automated drafting, avoiding instances from becoming severe, hastening recovery, boosting productivity, and enhancing welfare [34]. In addition, lame cows tend to spend less time eating, with shorter bouts, and eat less during the day [35, 36]. Depending on the technology, the expenses of automated lameness identification may be too expensive. However, in order to improve the sensor detection performance and further improve the system for various physiological states like oestrus, illness, calving, or body condition score (BCS), it is required to go forward with the downscaling of the present systems [37]. A single accelerometer per cow is a particularly cost-effective technique, but there are still a number of barriers to overcome before this technology is widely used on farms. Schlageter-Tello et al. [38] state that most automated locomotion scoring devices measure and analyse cows' movement and behaviour parameters using sensors and mathematical algorithms in an attempt to mimic human observers. The employed technologies can be divided into three categories: kinetic (ground reaction force systems, force-scale weighing platforms, and kinetic variations of accelerometers); kinematic (pressure plate/load cell solutions, image processing techniques, and activity-based techniques); and indirect methods, which primarily include behaviour technologies and individual cow milk production measuring technologies. **Table 1** summarises scientific efforts for detecting lameness in dairy cows using kinematic and kinetic techniques.

2.2 Mastitis

Mastitis is one of the most important disease affecting dairy cows. It leads to pain in contaminated animals and has been shown to be harmful to their welfare and the profitability of dairy farms on a worldwide scale [54, 55]. Since the adoption of robotic milking systems (**Figure 2**), dairy farmers have been concerned with developing adequate mastitis control strategies in their herds. The creation and application of control strategies that includes pre and post-milking teat immersion, proper milking practices, and the limited use of antibiotics in drying only in affected cows has led in a considerable drop in infectious microorganisms. However, when mastitis pathogens occurred, researchers tried to limit the use of antimicrobial drugs while protecting animal welfare and adhering to uniform standards for unnecessary usage. Thus, despite significant improvements in mastitis management over the previous decade, mastitis will continue to be a major focus of future studies [56].

Cost - effective monitoring of mastitis by automated technologies gives an ideal chance to carry out early therapeutic interventions and reduce antibiotic misuse, so boosting cow health and welfare, reducing discomfort and pain, improving recovery rates, and enhancing farm economic sustainability [57, 58]. Effective diagnostic techniques can speed up and improve the management of mastitis and encourage the proper use of antimicrobials [59]. It is also important to be able to properly evaluate the severity of clinical mastitis in terms of addressing treatment success [60] and adopt treatment safety protocols as needed.

2.3 Somatic cell count (SCC)

Health management is necessary for sustaining economical and sustainable dairy farming. The most common udder health indicator for dairy cows is somatic cell

Approach	LS	n	Locomotion test layout	SE (%)	SP (%)	Accuracy (%)	Reference
Kinematic							
Gaitwise	1–3	159	Alley 4.88 m long and 0.61 m wide	76–90	86–100		[39]
Gaitwise	1–3	40	Active surface of 4.88 m long and 0.61 m wide.				[40]
Gaitwise	1–3	36	Active surface of 4.88 m long and 0.61 m wide	88	87		[41]
Kinetic							
3D Accelerometer	1–5	12 + 36	13 m long and 1.3 m wide passageway			>60	[42]
Ground force reaction	1–5	610	Stepmetrix system	35	85	—	[43]
Ground force reaction	1–5	83	Two parallel force plates	90	93	AUC = 0.98	[44]
Ground force reaction	1–5	105	Four-force plate-balanced system	50–100	91–100	—	[45]
Ground force reaction	1–5	261	Two parallel force plates cow walks over	100	100	AUC = 0.70–0.99	[46]
Ground force reaction	1–5	346	Two parallel force plates cow walks over	52	89		[47]
Ground force reaction		6	Two parallel floor-plates loading platform–126 × 122 × 18 cm	91–97			[48]
Load cells and platform	1–5	57	Four force plates cow stands on			AUC = 0.64–0.83	[49]
Load cells and platform	1–5	57	Four force plates cow stands on			AUC = 0.67	[50]
Load cells and platform	0–13	42	Platform with 4 independent sealed load cells	75–97	60–90	AUC = 0.84–0.87	[36]
Load cells and platform	1–5	73	Four force plates cow stands on	100	58	86–96	[51]
Motion sensor		10	Motion sensor attached hind left limb	74.2	91.6	91.1	[52]
Motion sensor		65	Dairy cow individual sensor			AUC = 0.71	[53]

LS, locomotion score; n, number of cows; SE, sensitivity = True Positive/(True Positive+False Negative) × 100; SP, Specificity = True Negative/(True Negative + False Positive) × 100; AUC, area under the curve.

Table 1.
Summary of research findings for detecting lameness in dairy cows using kinematic and kinetic techniques.

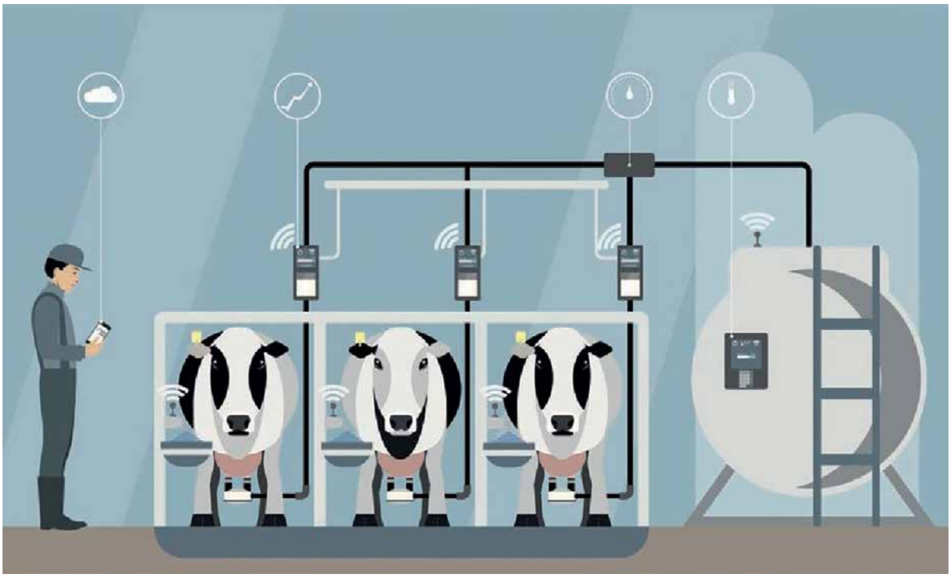

Figure 2.
A schematic of a robotic milking facility in which dairy cows can decide the time and frequency of milking.

count (SCC), which is tested at the quarter, cow, and bulk tank levels. In automatic milking systems (AMS), completely automatic online analysis devices are available to monitor SCC at the farm during each milking [61]. Moreover, from the results of the online SCC, a number of additional cows and quarter level factors important for udder health are recorded in these systems [62]. The SCC may be used to monitor intramammary infection to some extent, and the industry has progressed toward inventing novel sensors that are specifically developed for udder health monitoring. This provides a considerable increase in the quantity of data available for udder health management, for example, which may also use as phenotypes for breeding programmes. In addition to SCC measurements taken on a regular basis, a number of additional cow level and quarterly parameters judged important for udder health are recorded in the AMS at each milking [63].

2.4 Infrared thermography

Infrared thermography (IRT) is a non-invasive method that permits reliable temperature assessment from a distance and has several applications in animal science [64, 65]. Early mastitis detection in dairy production has been achieved with the use of IRT. Despite its demonstrated ability to diagnose mastitis, manual animal analysis has limits because it is time-consuming and needed a trained examiner [66]. In order to discriminate between cows with normal and increased SCC, Zaninelli et al. [67] applied software that detected the udder thermogram pixel with the highest temperature. When compared to the current gold standard of manual evaluation, the findings of automatic analysis of the thermograms of bovine udders that had suffered intramammary *E. coli* exposure indicated encouraging signs of clinical mastitis. We assume that the high temperatures seen with manual analysis occurred because warmer areas, including the udder-thigh cleft, were included, whereas these regions are omitted by automatic segmentation [68]. This technique may also be used to identify changes in internal body temperature, such as fever. However, infrared thermography should not take the place of an individual animal examination and is only intended to be used as a tool for automated health surveillance [69].

2.5 Body condition scoring

Body condition is an important factor for herd management and welfare. The dairy cow's body condition is highly correlated with their health, metabolic activity, and the composition of the milk during lactation [70]. Assessment of body condition is an indirect measure of the level of body reserves, and deviations from show the overall variation in the energy balance [71, 72]. Regular measures of body condition are based on visual observation and palpation of particular body parts to provide a score that evaluates the adipose tissue and muscle mass deposits [73]. This evaluation method, commonly referred to as the body condition score (BCS), has captured attention as a useful technique for managing dairy herds [74].

BCS observations can be done by visually or using a combination of visual signs with bone structure palpation, and the amount of subcutaneous fat. The backbone, pins, tail head, long ribs, short ribs, hips, and rump are the key segments for BCS assessment [75]. Different scoring scales have been developed all around the world throughout the years. In the United States, for example, a five-point scale method was mostly used, proposed by Windman et al. [76]. Ferguson et al. [77] suggested a scale of 0 to 5, subdivided into 0.25 centesimal intervals, to measure body condition, namely the adipose tissue of the cow's lumbar and pelvic parts. Despite widespread agreement among dairy farmers, nutritionists, and herd management regarding the benefits of BCS assessment, various reasons restrict its adoption [78], subjectivity in judgement can result in different scores for the same cow, and on-farm technician training is difficult and time-consuming [79]. Furthermore, in order to obtain useful data, cow measurements must be recorded every 30 days across the lactation period [80], increasing the extra cost and difficulty of obtaining BCS data. To address these limitations, different alternatives solutions have been developed within the approach of the PLF, with extremely promising outcomes. The most innovative options use image capture and recording as vision-based body condition score systems, which resemble traditional BCS assessments in some ways. Ultrasound is another imaging technique that has been used to determine body and carcass composition [81]. This approach is commonly used to monitor body condition in small ruminants [82, 83], swine [84], and cattle [85]. Recent studies [86, 87] demonstrated the utility of applying ultrasound to examine the body reserves of cows by scanning the body areas associated with the BCS assessment, such as the ribs, pin, tail-head, and lumbar spine. Despite its excellent accuracy for BCS prediction, the cows must be individually confined to obtain the ultrasound pictures, making this technology less ideal for evaluating large numbers of animals over time. Therefore, larger farms with hundreds of animals should not use this method. In order to achieve a BCS evaluation of animals in motion, the ultrasonic technique is only used for timely analyses or the validation of other approaches, such as those supported by cameras [88, 89].

2.5.1 Vision-based body condition scoring systems

Currently, many vision-based BSC monitoring systems, including thermal imaging [90], 2D imaging [91], and 3D imaging technology [92, 93], have been developed and tested. With examples like Fourier transformation [94] and machine learning

Sensor	N	Sensor position	Accuracy	Accuracy within BCS points deviation (%)			Reference
				0	0.25	0.5	
2D Sensors							
Black-and-white	2571	60 to 70 cm above the cows' backs			93	100	[97]
AXIS 213 PTZ	286	3 m above ground	Error = 0.31				[78]
Sony, DCR-TRV460	46	3 m above ground	R2 = 90				[98]
Hikvision DS-2CD3T56DWD-I	8972	2.6 m the ground. Milking passage	R2 = 98.5				[75]
Hikvision DS-2CD3T56DWD-I	2231	Cows walk below the camera			65	95	[97]
3D Sensors							
Mesa 3D ToF	40	Hand-held setup			79	100	[99]
SR4K time-of-flight	540	Above electronic feeding dispenser	R2 = 89				[100]
ToF MESA SR4000	1329	Above DeLaval AWS 100	R = 84				[101]
Asus Xtion Pro	82	2 m above ground	R = 96				[102]
PrimeSense™ Carmine	116	1.5 m from the cows' backs			71	94	[103]
Microsoft Kinect v2	1661	2.8 m above ground-milk parlour		40	78	94	[65]
Intel RealSense D435	480	3.2 m above ground			77	98	[100]
Microsoft Kinect v2	38	3 m above the ground		56	76	94	[93]
3D ToF	52	3.4 m above ground-rotary parlour	MAPE = 3.9				[101]

n, number of cows; ToF, time of flight; BCS, body condition score; R, correlation coefficient; R2, coefficient of determination; MAPE, mean absolute percentage error.

Table 2.
Summary of study measuring cow body condition score with 2D and 3D sensors.

[95], data analysis techniques have been used to track the development of sensors, which boost the capability of working systems. There are still limitations to completely automated systems, despite the advancements that have previously been made. However, with the advancement of cameras and software, we are getting closer to an automated and objective BCS. The guesswork and errors associated with conventional scoring are eliminated by vision-based approaches, while the efficiency may be significantly increased. These factors clearly act as the foundation for developing machinery that producers consider to be effective [96]. The study on measuring cow body condition score using 2D and 3D sensors is summarised in **Table 2**.

The Welfare Quality standards now incorporate BCS as an animal-based indicator connected to livestock feed [102]. Similarly to what is currently being done with other species (e.g., Eye Namic for Poultry and Swine [17]), by continuously monitoring health and welfare in real time, PLF technologies have shown to be a step forward in the individual assessment of cows [14, 103].

3. The potential of PLF for assessing welfare animal-based indicators of dairy cattle

Because welfare is a complicated multi-dimensional phenomena, assessing the welfare of dairy cows and other farm animal species usually involves time-consuming and costly audits [102]. On the other hand, with recent advances in sensor technology, the sole purpose of PLF, which is continuous real-time on-farm monitoring of individual animals to enhance production/breeding, health and welfare, and environmental sustainability, is already being approached in different aspects of dairy cattle production [103]. As with the Welfare Quality® protocol, the implementation of dairy cow welfare evaluation has considerable constraints, as it is time-consuming [23] and lacks interaction with trained users on the value of various welfare criteria [104]. In addition to shortening the evaluation period, many researchers proposed changes to the calculations, such as the one described by Van Eerdenburg et al. [22] for drinking water. Furthermore, the welfare calculations required more adjustable techniques, mainly for the total score [23, 104]. As a result, the ability to use PLF solutions to assess the animal-based indicators of lameness, mastitis, and body condition presented in this review could well be much appreciated. Because of the recent development and validation of different PLF solutions, as shown by the discussed advances, it is now possible to address the three animal-based indicators listed by commercial PLF technologies. In addition, a recent review [13] noted that in order to properly use the continuous measurement and individual monitoring of cows, some of the protocol criteria would need to be modified. This modification can rely on animal-based welfare measures, such as those examined in this paper and others, as explained by Tuyttens et al. [23], who reviewed the Welfare Quality Protocol and discovered a more user-friendly, time-efficient approach in assessing dairy cattle welfare with the inclusion of only six animal-based indicators. Various farm animal welfare frameworks, such the five domains model [101], will also have room. Researchers studying farm animal welfare are becoming more interested in the five domains model, and they are also discussing about the possibility of using the PLF with this model. With the advancement of PLF technologies, it is now unquestionably possible to monitor cow welfare in real time with the use of animal-based indicators. Therefore, based on recent scientific research and technological advancements (e.g., Stygar et al. [14]), significant PLF developments are assumed to occur soon, opening the window of opportunity for monitoring and improving the welfare of dairy cows.

4. Challenges for the future

Precision livestock farming is recognised as key for future dairy producers since it allows for regular monitoring of animal health and welfare during production. The advancement of applying technology for monitoring lameness, mastitis, and body condition in dairy cows is highlighted in this chapter. Accurate continuous monitoring systems that eliminate false alarms are required for farmers to accept and implement these technologies for these challenges, which have been identified as animal-based indicators. Therefore, a detailed early warning system is required to monitor the health of dairy cows in order to prevent the development of more serious diseases and welfare issues. Finally, research into dairy cow welfare technologies has provided various indications that might be automatically monitored and integrated into an evaluation framework.

5. Conclusion

Farm animal welfare is an increasing problem all over the world. There is a considerable need in milk production to analyses the welfare of dairy cows. The Welfare Quality project's procedures have been used in one of the most sound assessment initiatives. These methods primarily assist in the examination of cow welfare using animal-based indicators. However, analysing these indications takes time and money, thus adopting precision livestock farming (PLF) technologies is a viable option that is becoming a reality in the dairy sector. This chapter discusses advancements in PLF solutions, generally in the previous 5 years, along with animal-based indicators of lameness, mastitis, and body condition in dairy cattle farming.

Conflicts of interest

The authors disclose that they have no conflicting interests.

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Chapter 8

Overview of Animal Welfare Aspects of Bali Cattle with Confined Typology in Sumbawa Regency, NTB, Indonesia

Sudirman Sudirman, Amrullah Amrullah and Asrul Hamdani

Abstract

The quality of life of cattle will affect their productivity, where productivity is an indicator of animal welfare. Sumbawa is one of the national cattle source areas in Indonesia, both as a producer of beef cattle and seed cattle. The research has been carried out using a survey method, collecting data through structured interviews using questionnaires, field observations and the Animal Needs Index (ANI) with 40 respondents. The purpose of the study was to determine the level of welfare of Bali cattle with the Confined typology in Sumbawa Regency. The results showed that the total ANI score in the study area was 15.32, which was included in the almost prosperous category. The recommendation is that it is necessary to improve the aspect of being freedom from discomfort (FDC) and the aspect of being freedom to express natural behavior (FENB) to improve animal welfare through increasing awareness and understanding of farmers and there needs to be government policy intervention in the context of implementing animal welfare in Sumbawa Regency as a efforts to increase the productivity of Bali cattle.

Keywords: animal welfare, ANI, Bali cattle, confined, productivity

1. Introduction

The definition of animal welfare in the Law of the Republic of Indonesia number 41 of 2014 concerning amendments to Law No. 18 of 2009 concerning Animal Husbandry and Animal Health clause 1 Section 42 is all matters relating to the physical and mental state of animals according to behavioral measures. Natural animal nature needs to be implemented and enforced to protect animals from any person's inappropriate treatment of animals that are used by humans. Animal welfare targets are all animals that interact with humans where human intervention greatly affects the survival of both animals in confinement, livestock and slaughter animals, working animals and pets [1]. The quality of life of animals will affect their productivity, where productivity is an indicator of animal welfare. The application of animal welfare aspects in the livestock industry is recognized as having the potential to increase animal productivity and improve meat quality [2].

Parameters for evaluating animal welfare that have been internationally recognized by classifying are The Five Freedoms [3] as follows: 1. Freedom from hunger and thirst; 2. Freedom from discomfort; 3. Freedom from pain, injury and disease; 4. Freedom to express natural behavior; 5. Freedom from fear and distress. Although aspects of animal welfare are grouped into two of five freedoms, the first four freedoms are to relieve suffering and the second freedom is to express normal behavior [4]. The application of animal welfare in cattle farming can mean placing cows in adequate facilities, protection from pain and protection from environmental extremes, such as air temperatures that are too hot or too cold [5].

Sumbawa Regency, Nusa Tenggara Barat (NTB) is one of the national cattle source areas in eastern Indonesia, both as a producer of beef cattle and seed cattle. Bali cattle population growth in Sumbawa is very dynamic starting at 0.34% in 2017; 4.69% in 2018; 1.36% in 2019; 1.33% in 2020 and − 3.78% in 2021. Meanwhile, growth other than Bali cattle such as Sumbawa cattle and crossbreed cattle was 1.47% in 2017; 19.54% in 2018; 81.14% in 2019; 70.33% in 2020 and −3.78% in 2021 [6].

The Bali cattle production system in Sumbawa, the results of the 2017 research, contained 34 typologies seen from the annual maintenance cycle. All of the typologies mentioned above have three typologies that are the most dominant, namely typology 6/6; tethered typology; and confined typology [7]. Currently, the typology that is increasingly being applied by farmers is the confined typology, the advantages of the confined typology are because there is a cattle insurance program, the ease of accessing people's business credit (PBC) for cattle business development from state-owned banks, while the 6/6 typology and tethered typology stagnant and even tends to decrease due to the change in land function and the existence of regional regulations that prohibit the free release of livestock. Therefore, the quality of life of Bali cattle with confined typology as seen from the knowledge and understanding of farmers in raising livestock which is part of animal welfare has never been reported. Based on the above phenomenon, an animal welfare level study with confined typology has been carried out in Sumbawa Regency.

2. Animal welfare view in Indonesia

In Indonesia, issues of animal welfare and human rights were raised by the Indonesian Veterinary Association and animal rights activists in the 2000s. Various campaigns were launched, including improving the methods of slaughtering animals, sacrificial animals, to comply with animal welfare principles. The campaign was carried out on inter-island cattle transportation that often tortures animals, such as hanging cattle from one leg or throwing cattle from a truck [8].

The lack of information and regulations on animal welfare in cattle farming practices has an impact on the lack of animal welfare practices in the field [9]. Various studies have been conducted that focus on animal welfare, such as in several farms in the Pangkal Pinang area, Bangka Belitung Islands Province using the ANI method with five categories of animal welfare, namely movement, social contact, floor quality, light and air and cage cleanliness. The study shows that beef cattle are generally in a prosperous condition with a total ANI score of 23.8 [10]. The same thing was done by Sulistiawati and Wulandari [5] in the Nganjuk area, East Java Province with the results of the study showing that animal husbandry quite meets animal welfare standards (ANI category score 23) and almost does not meet animal welfare standards (ANI category score 12.8), meets animal welfare value standards if the total score is ANI category 32.

Animal welfare research on cattle slaughtered at the Banda Aceh Municipal Slaughterhouse (RPH). The animal welfare parameters observed included three aspects, namely transportation, shelter and slaughter. The three aspects are compared with the recommendations of Meat Livestock Australia (MLA) and the Indonesian National Standard 02–4509-1998. The method used is scoring assessment. Based on the scoring assessment of the shelter aspect and the slaughter aspect, the animal welfare of the slaughtered cattle at the Banda Aceh Municipal RPH is considered good in fulfilling the animal welfare aspect, while the transportation aspect is considered sufficient in meeting the animal welfare of the cattle slaughtered at the Slaughterhouse [11]. The development of the implementation of social welfare policies in the form of proposals through academic reviews as a basis for implementation. The concept of an animal welfare assessment system for sustainable cattle production in Indonesia which is based on protocols, human resources and the government. These three main elements in the animal welfare assessment system will be integrated to build sustainable cattle production through better animal welfare practices [9].

3. Welfare measurement techniques for Bali cattle in Sumbawa

The research was conducted in July–October 2021 with four regions, namely west, east, north and south with 40 respondents. The respondent's criteria are Bali cattle farmers with a confined typology production system that has a cage with a minimum population of 10 Bali cattle with at least 3 years of livestock experience. Primary data were collected through direct interviews and secondary data from government agencies as well as direct observation for measurement (cage, feed, livestock behavior) and documentation. Data analysis used the Animal Needs Index method [12]. The determination of the rating scale was done using a Likert scale of 1–5 (**Table 1**).

4. Aspects of animal welfare for Bali cattle in confined typology

In confined typology, there are limitations for livestock in accessing feed ingredients because everything is regulated. The role of livestock rearing management is of particular concern to livestock because it will support an increase in productivity through the application of animal welfare. Good management occurs when public awareness and knowledge are at a high level so that livestock can be guaranteed in terms of access to feed ingredients, drinking, comfort, health and normal behavior.

Categori	Total Score	Range Score
Very prosperous	25	21–25
Prosperous	20	16–20
Almost prosperous	15	11–15
Not prosperous	10	6–10
Very not prosperous	5	0–5

Source: primary data, processed 2021.

Table 1.
Classification of cattle welfare level.

4.1 Knowledge and understanding of farmers

The understanding and knowledge of farmers on livestock welfare or animal welfare need to be known as a supporting aspect in the context of deepening the aspects that are the determining variables. There is a positive relationship between humans and animals, especially the adequate knowledge and skills possessed by farmers [13].

Table 2 shows the knowledge and understanding of farmers (KU1) about animal welfare with an average value of 1.64 (do not know category). This is due to the factor of not getting information about livestock welfare received by farmers independently and through socialization or technical guidance. Handling and productivity of livestock can be increased through training programs aimed at improving the attitudes and behavior of farmers toward their livestock [14, 15]. Specific training and skills can be beneficial [16].

This condition will certainly affect the farmers' understanding of animal welfare itself. The results of the study, in **Table 2**, show that only 1.56 breeders' have a lack of understanding of the KU2 value about animal welfare. Knowledge and understanding of farmers who do not know and understand as a result of the lack of socialization or information received by farmers is KU3 = 1.41 about animal welfare. The results of the research on the level of knowledge and understanding as well as getting information about animal welfare or cattle welfare in the Sumbawa district with a score of 1.54 is in a low category.

Animal welfare status is not always constant due to fluctuations in the factors responsible for good or bad welfare. Therefore, animal welfare status can be good, bad or somewhere in between [17] and varies with time. In general, if the cattle are healthy, comfortable, well nourished, free from pain, fear and distress and able to express their innate behavior, their welfare will be fulfilled [3]. The fulfillment of animal welfare is obtained from good husbandry, including the prevention and treatment of disease, humane handling and slaughter, and the provision of adequate nutrition and shelter [18].

4.2 Freedom from hunger and thirst

The American Society for the Prevention of Cruelty Animals [19] states that the level of animal welfare is said to be good if the livestock is free from hunger and

Region	Knowledge and understanding			Total	Average
	KU1	KU2	KU3		
East	2.20	2.10	2.10	6.40	2.13
West	1.38	1.13	1.13	3.63	1.21
North	1.30	1.40	1.00	3.70	1.23
South	1.70	1.60	1.40	4.70	1.57
Total	6.58	6.23	5.63	18.43	6.14
Average	1.64	1.56	1.41	4.61	1.54

Source: Primary data, processed 2021.
KU1 = know, KU2 = understand, KU3 = get information.

Table 2.
Knowledge and understanding of farmers about animal welfare.

Region	Indicator freedom from Hunger and Thirst							Total	Average
	FHT1	FHT2	FHT3	FHT4	FHT5	FHT6	FHT7		
East	3.40	3.70	3.10	2.80	3.40	3.40	2.50	22.30	3.19
West	2.88	2.88	2.63	3.13	3.63	3.00	3.00	21.13	3.02
North	2.70	3.30	2.50	3.10	3.40	3.20	3.10	21.30	3.04
South	2.70	3.60	2.50	3.10	3.20	3.50	3.40	22.00	3.14
Total	11.68	13.48	10.73	12.13	13.63	13.10	12.00	86.73	12.39
Average	2.92	3.37	2.68	3.03	3.41	3.28	3.00	21.68	3.10

Source: Primary data, processed 2021.
FHT1 = provide/feed as needed; FHT2 = provide/give water as needed; FHT3 = type of feed given; FHT4 = amount of feed given; FHT5 = how to feed; FHT6 = signs of cattle not feeling hungry and thirsty; and FHT7 = loss when cattle feel hungry and thirsty.

Table 3.
Freedom from hunger and thirst.

thirst. The aspect of consumption is a concern in animal welfare, this is indicated by the fulfillment of feed and water consumption so that livestock no longer feel hungry and thirsty. Livestock must have access to adequate feed and water according to their age and needs to maintain normal health and productivity and prevent hunger and thirst, malnutrition or prolonged dehydration [13]. The aspect of being free of hunger and thirst is the main measuring tool in assessing the level of animal welfare.

Table 3 shows that the supply of feed according to needs with a value (FHT1 = 2,92) is still in the fairly good category, which means that the understanding and awareness of farmers in the context of providing feed that is in accordance with needs, has an impact on feed management. In an intensive cattle production system, all cattle are locked up and all rely on farmers for basic needs, such as cages, feed and drinking water [4]. Adequate water supply with a value of FHT2 = 2.68 shows awareness and understanding of the importance of water consumption for livestock and water as a basic need looks quite good. This is indicated by the provision of water ad libitum to livestock, there are also others who provide drinking water to cattle an average of two times a day in the morning and evening.

The provision of water in a confined typology should be ad libitum as the role of water in the body is very important because the largest nutrient in the body composition of livestock is water. The need and consumption of water depend on several factors, such as temperature, humidity, water temperature, production level, pregnancy status, physical activity, growth rate, animal size, type of food, water content of feed, salt content consumed and dry matter consumption [20, 21]. Consideration of good water quality is also given to reduce the incidence of disease and economic losses [22]. Understanding issues of water quality and consumption is critical to cattle nutrition and management [23].

The type of feeding that is suitable for cattle with an average value of FHT3 = 2.68 indicates that the type is quite varied depending on the season. In the rainy season, farmers rely on forage in the form of various types of natural grass, including types of legumes such as wild or cultivated *leucaena*. The limited number of farmers who cultivate superior grasses such as elephant grass, king grass, mott elephant grass and legume cultivation (*leucaena, indigofera, sesbandia glandiflora*) is a limiting factor in providing the varied feed. There is an additional type of feed in the form of concentrate (*rice bran*, *zea mays*) although still a small number of farmers apply this.

However, in the dry season, farmers rely on the remaining agricultural products in the form of rice straw, corn straw, corn cobs, corn husks, zea mays, green bean straw and *leucaena,* which still survive in the dry season. The amount of appropriate feed for cattle is quite good with an average value of FHT4 = 3.03, meaning that farmers have sufficient ability to understand the feed needs of cattle.

Forage quality affects dry matter consumption, so increasing forage quality will be followed by an increase in total digestible nutrients (TDN). The existence of the ability of farmers to assess signs of the adequacy of feed by looking at signs of cattle feeling full, cattle not wanting to eat anymore, and based on the experience of raising livestock for generations. In addition, the understanding of farmers through socialization or technical training on the adequacy of animal feed contributes to a fairly good FHT4 value. The way of feeding the category is quite good with an average value of FHT5 = 3.41 indicating that the awareness of farmers about regularity in the feeding pattern has been carried out quite well. Regular feeding with an average frequency of feeding 2–3 times a day, namely in the morning, afternoon and evening, has become a habit and culture for raising livestock for the Sumbawa people. So that the certainty of cattle feeling full is a target in feeding management, this can be seen from the value of the ability of farmers to recognize signs of livestock feeling hungry and thirsty quite well with an average value of FHT6 = 3.28 with a fairly good category. Understanding of hunger and thirst such as the left side of the cattle's stomach is flat, the cattle will be aggressive when there are people in the cages, the cattle are restless, make noises, do not want to stay still, and always scavenge or lick the feed. The ability to understand the signs of livestock feeling hungry and thirsty is an advantage possessed by farmers in the Sumbawa Regency as a real form of the evaluation process in feeding management. The awareness of farmers about the importance of livestock free from hunger and thirst can be proven by looking at the ability of farmers to assess the impact or loss it causes.

Understanding the mechanism of regulation of consumption/intake and regulation of energy balance in ruminants is very important to increase the production efficiency [24]. Changes in behavior are caused by variations in hunger [25]. The average value of losses when cattle feel hungry and thirsty (FHT7 = 3.00) is quite good, meaning that farmers can assess and ascertain what consequences will occur. Various losses that will be caused in the form of livestock will experience weight loss and are susceptible to disease so that they experience losses in their business, besides that, it takes a long time to maintain a reduction in the cost of treatment and care for disease as well as a reduction in mortality rates and improvements in health will reduce economic losses [2]. Based on the assessment aspects above, in general, the management of feeding and drinking in the Sumbawa district with an average value of 3.10 is still in a fairly good category in terms of being free of hunger and thirst. The feeding schedule for captive cattle is determined by the farmer and the feeding schedule four times a day is categorized as very good [19].

4.3 Freedom from discomfort

The aspect of being free from discomfort in **Table 4** shows that the knowledge of farmers about signs of cattle feeling comfortable in cages can be seen from the average value of FDC1 = 3.16 with a fairly good category. Some signs of cattle feeling comfortable in the cage based on the understanding of the farmer such as cattle are not restless, normal breathing is not gasping for breath, cattle are not rebellious, cattle tend to be silent, do not rebel, want to get out and are calm in the cage by sleeping

Region	Freedom from discomfort									Total	Average
	FDC1	FDC2	FDC3	FDC4	FDC5	FDC6	FDC7	FDC8	FDC9		
East	3.40	3.20	2.80	2.80	2.30	2.90	3.00	2.80	3.80	27.00	3.00
West	3.13	3.00	2.88	3.13	1.00	1.13	3.13	1.00	3.00	21.38	2.38
North	2.90	3.10	3.40	3.10	1.60	1.30	3.10	1.00	3.80	23.30	2.59
South	3.20	3.40	3.10	3.10	2.40	2.20	2.90	1.00	3.20	24.50	2.72
Total	12.63	12.70	12.18	12.13	7.30	7.53	12.13	5.80	13.80	96.18	10.69
Average	3.16	3.18	3.04	3.03	1.83	1.88	3.03	1.45	3.45	24.04	2.67

Source: Primary data, processed 2021.
FDC1 = sign of cattle feeling comfortable in the pen; FDC2 = sign of cattle not feeling comfortable; FDC3 = cage position is suitable for comfort; FDC4 = size/capacity/capacity of the cage; FDC5 = information on how to make a good cage; FDC6 = received information/counseling on cage sanitation; FDC7 = adequate and comfortable cages equipment; FDC8 = cages ventilation; and FDC9 = in the morning sunlight.

Table 4.
Freedom from heat and feel comfortable.

comfortably in the cage. Ways to get the comfort of livestock, it is necessary to protect them from extreme areas, such as heat, rain, and wind [26] as well as the management of housing by farmers, as one of the fulfillment of the basic needs of livestock other than food and water [4]. Farmers have quite good knowledge about the signs of livestock feeling uncomfortable in the cage, this can be seen from the average value of FDC2 = 3.18 with a fairly good category. The standard of livestock comfort is obtained by making the construction of the floor of the cage that is not wet and slippery and easy to clean [26].

A good position and location of the cage is the most important thing that affects the comfort of livestock in the cage. Farmers must prepare a shady place and comfortable rest for their livestock [4]. The knowledge of farmers that the direction of the cage must receive morning sunlight so that the direction of the cage is mostly facing east. This can be seen from the mean value of FDC3 = 3.04 included in the good enough category, meaning that farmers have good knowledge and understanding of building cages. The comfort of livestock in cages can also be influenced by the density of livestock in cages, this can be seen from the mean value of FDC4 = 3.03 with a fairly good category. Knowledge and understanding of farmers about power the livestock capacity is quite good, it can be seen that the planning for the construction of the cage is adjusted to the number of cattle to be kept. The current average livestock capacity is 3 m^2/head. The standard housing [12] equipped with booths is 2.2 m^2/head cattle for beef cattle weighing 350 kg.

There is limited information on how to make suitable cattle cages, the standard for making good cages is that the floor is not slippery and easy to clean [26] and the placement of the cage in a shady position [4] must be considered and should not be ignored. This can be seen from the average value of FDC5 = 1.83 in the less category. Lack of information about building good cages and meeting the requirements for livestock comfort is still not good in the form of socialization and counseling only relying on experience and knowledge passed down from parents. Understanding of cages for livestock cattle is to limit the movement space so that the accumulation of meat and fat occurs quickly and the weight gain of livestock is faster [27].

The cleanliness of the cage is also important to maintain the comfort of the livestock, therefore, the floor of the cage must be easy to clean [26]. Farmers' knowledge of good sanitation methods is still lacking, this can be seen from the value of FDC6 = 1.88 in the poor category. This is due to the lack of socialization and counseling because many farmers ignore good cage sanitation methods only relying on experience. In addition, the provision of supporting equipment also needs to pay attention to the comfort of livestock, meaning that farmers have sufficient knowledge of the provision of cage equipment that meets the requirements for use in cages and does not endanger livestock. It is the farmer who can choose and plan whatever the livestock needs [28]. This can be seen from the FDC 7 = 3.03 in the fairly good category. By relying on experience and simple manual equipment the provision of equipment used in cages but not harmful to livestock.

Farmers' understanding of ventilation is not needed, this can be seen from the average value of FDC8 = 1.45 in the category not needed because an open cage system can guarantee air circulation in the cage, so it does not require special ventilation. Optimal air quality is obtained from open cages [12]. Open cages provide a minimum of 0.45 m^2/AWU with unrestricted access to open air, with a minimum opening height of 1 m [12]. Knowledge and understanding of farmers about a good position of the cage building can enter the morning sun as seen from the average value of BTN9 = 3.45 with a poor category. The importance of the morning sun entering the cage is mandatory in order to maintain the health of livestock. Based on the above components, the aspect is free from heat and feeling the comfort of livestock is quite good, this can be seen from the average value of FDC = 2.67 with a fairly comfortable category. The shape of the cage is quite open and has good air circulation in the cage so that it makes the cattle comfortable and enough sunlight illuminates the cage [10]. This condition [29] makes the place to lie down is always dry. Sunlight hitting the eyes of animals should be used in research with consideration, the percentage of direct sunlight that enters through the windows is affected by the projection of roofs, trees, buildings blocking the sky [12].

4.4 Freedom from pain, injury and disease

Table 5 shows that the cattle have experienced illness/injury with an FPID1 = 3.73 category of never. There were incidents of livestock getting injured or injured as a result of the transportation process, when they came out of the cage, they were scratched by the fence while the cattle got sick during the rainy/transient season in the form of scabies, bali zekte, pink eye and intestinal worms. The appearance of illness both physically and physiologically can be caused by stress in animals [30]. Therefore, it is important to raise or tame cattle with gentleness and respect without violence and pain. This is important because in Indonesia, farmers must prepare livestock in a safe, healthy, disease-free, intact condition without defects and halal (good) to be consumed [31]. Therefore, it is also important for farmers (producers) to choose livestock with better disease resistance early in life [32].

The actions taken by most farmers by consulting with livestock health officers have been carried out, this can be seen from the FPID2 = 3.31 value in the category of having done. This is done as a form of farmer awareness to protect and maintain the health of livestock from disease, following the statement that says that farmers must be able to prevent, diagnose and treat livestock if they are exposed to disease [4]. Cattle health needs to be considered when raising cattle, because to get good quality meat, cattle must be healthy [10]. The success of a cattle farming business is largely determined by the health of the livestock itself [33].

Protection and treatment measures are due to the lack of knowledge and skills of farmers in terms of treatment and livestock health, but other efforts are made with

Region	Freedom from pain, injury and disease										Total	Average
	FPID1	FPID2	FPID3	FPID4	FPID5	FPID6	FPID7	FPID8	FPID9	FPID10		
East	4.00	2.90	4.60	4.60	4.70	3.50	2.40	4.10	3.10	4.20	38.10	3.81
West	3.50	3.25	4.63	4.63	5.00	3.75	3.38	2.25	2.75	4.00	37.13	3.71
North	3.70	3.50	4.50	4.30	5.00	3.30	2.60	3.40	2.70	4.00	37.00	3.70
South	3.70	3.60	4.70	4.60	5.00	4.30	3.70	2.70	2.10	4.10	38.50	3.85
Total	14.90	13.25	18.43	18.13	19.70	14.85	12.08	12.45	10.65	16.30	150.73	15.07
Average	3.73	3.31	4.61	4.53	4.93	3.71	3.02	3.11	2.66	4.08	37.68	3.77

Source: Primary data, processed 2021.
FPID1 = ever been injured/sick; FPID2 = consultation with health workers; FPID3 = injured/fallen in cage; FPID4 = fight/horn each other; FPID5 = injury/illness due to equipment; FPID6 = giving a burn stamp; FPID7 = separation of calf, cow and bull; FPID8 = separation of sick cattle; FPID9 = satisfied with the current condition of the cage; and FPID10 = needs adjustment.

Table 5.
Freedom from pain, injury and disease.

local knowledge using ingredients that are passed down from generation to generation. Other factors that have the opportunity to cause livestock to be injured/injured/fallen sometimes occur, this can be seen from the mean value of FPID3 = 4.61 for the occasional category. The high FPID3 value was also caused by the condition of the cage floor which was less inclined and fell when the floor was wet and slippery. The floor is very important to provide a good grip to prevent cattle from slipping or falling [12]. In addition, poorly managed floors can cause injury to livestock hooves [12]. Lameness due to injury or disease of the legs is considered a major problem in cattle [34]. Another factor is cattle that are shocked or when the cattle are new and not yet tame when they enter the cage.

The incidence of cattle horning each other has never happened and suffered injuries, this can be seen with the value of FPID4 = 4.53 in the never category. This means that the chances of each other having a low-frequency horn occur because there is a barrier between livestock. The possibility of injury to livestock can also occur due to unsafe equipment during cage sanitation. The understanding and skills of farmers play a very important role, this can be seen with a FPID5 = 4.93 with the category of never occurring because the equipment used is not made of hazardous materials, such as iron or sharp tools, on average, farmers use materials in the form of wood, plastic or rubber so that the possibility of injury to livestock can be avoided.

The awareness of farmers in the maintenance and care of cattle is very good. This can be seen by avoiding things that can cause injury or illness to cattle in line with the opinion [35] that livestock should not be intentionally hurt, by no longer giving a sign in the form of a burn stamp to avoid livestock experience stress due to adverse activities/management. This can be seen by the average value of FPID6 = 3.71 for the occasional category. This condition occurs because the marking in the form of a burnt stamp is a sign given by the previous owner. In addition, marking is no longer necessary because livestock no longer mixes with other people's livestock. Another reason for farmers is the demand for consumers who prefer livestock without markings, such as qurban cattle and the reason for the economic value that livestock that do not have defects such as burn marks are higher. In efforts to prevent livestock from getting injured due to physical contact in the form of horns, it is necessary to separate the bull from the cow or the calf. This can be seen by the average value of FPID7 = 3.02 category ever.

Knowledge and understanding as well as experience of farmers are good to avoid physical contact that causes livestock to suffer injuries in the cage. In addition, the separation of male, mother and child cattle is also aimed at controlling the disease. This can be seen by the average value of FPID8 = 3.11 in the never category, meaning that when there is an incident of livestock experiencing illness, it must be separated from the group to facilitate handling and treatment. In addition, to avoid the occurrence of disease transmission that can harm the economy. The limitations of farmers with cage management are still limited, this can be seen by the value of FPID9 = 2.66, the category is quite satisfied. This is due to the limited manual and traditional cage equipment and the limited form and construction due to limited cage financing. Limited space and livestock unable to show some of their natural behaviors can lead to disease risk and high feed competition [4]. The existence of additional information through social media as well as an understanding of appropriate and good cage management creates a desire to improve the quality of the cage facilities, this can be seen from the average value of FPID10 = 4.08 categories. It is necessary to adjust and improve the quality of the cage facilities in order to improve the quality of management maintenance. Based on the overall component aspects of the assessment of being free from illness, injury and disease with a FPID value of 3.77 good category.

4.5 Freedom to express natural behavior

Opportunities for animals to move need to be assessed and express their natural behavior according to their behavioral needs [12]. Animal welfare is best demonstrated by the presence of several natural animal behaviors observed [4]. Freedom to express natural behavior is obtained by providing sufficient space, appropriate facilities and friends of the animal species itself for social interaction [4]. In addition, it is important to facilitate livestock so that they can behave normally when getting up, standing and lying down [12]. Livestock management techniques are important to use the natural behavior of the cattle themselves [35]. Currently, livestock behavior assessment can be assessed scientifically to determine the quality of life of individual animals [28]. Based on **Table 6**, the time the cattle were released outside the cage can be seen from the mean value of FENB1 = 2.69 in the category of never/no time. Farmers really need to prepare an outdoor area of about 3–5 m^2/AWU [12].

The knowledge of farmers about the importance of livestock being released at any time to express natural behavior, has been carried out by providing time for this. The frequency and duration of livestock access outside the room are important factors, with an average duration of more than or equal to 2 hours [12]. In addition to the availability of time to do body exercises and express natural behavior, the duration of time on a regular basis is important, this can be seen from the average FENB2 = 2.96 categories once a week. The duration of 1 full day once a week or equivalent to 51 days a year has been carried out by farmers regularly. The exercise pattern carried out by farmers is by walking the cattle outside the cage. This can be seen by the average value of FENB3 = 3.11 in the category of being invited for walks outside the cage for fattening efforts. The importance of livestock expressing natural behavior can be seen from the average value of FENB4 = 3.74 in the necessary category. Expressing normal behavior so that livestock can move freely, muscles are not stiff so that livestock do

Region	Freedom to express natural behavior				Total	Average
	FENB1	FENB2	FENB3	FENB4		
East	3.30	3.50	3.90	3.90	14.60	3.65
West	2.38	2.63	2.13	3.25	10.38	2.59
North	2.50	3.10	3.20	4.00	12.80	3.20
South	2.60	2.60	3.20	3.80	12.20	3.05
Total	10.78	11.83	12.43	14.95	49.98	12.49
Average	2.69	2.96	3.11	3.74	12.49	3.12

Source: Primary data, processed 2021.
FENB1 = free time; FENB2 = length of free time; FENB3 = maintenance model to freely express normal behavior; and FENB4 = need cattle to express natural/normal behavior.

Table 6.
Freedom to express natural behavior.

not cramp and suffer muscle injuries. The good health of livestock is influenced by the natural behavior of the animal [36]. Based on all components of the free aspect of expressing natural behavior with an average value of FENB = 3.12, the category is quite good.

4.6 Freedom from fear and stress

Farmers must be able to fulfill their responsibility to provide a well-managed cage environment to prevent stress on animals, including noise which can also cause stress [12]. The behavior of cattle to stress can reduce the productivity and health of livestock [37]. High levels of stress can reduce the response of the immune system and increase the incidence of infectious diseases [36]. **Table 7** shows the average value of FFS1 = 4.49, the category of cattle sometimes experiencing fear and stress from wild animal disturbances. There is protection in the form of care or control, that is always carried out by farmers. The position of the cage that is close to the road and far from the forest can reduce the chance of disturbance by wild animals, but there are some cases for farmers in the form of dog disturbance during the parturition of cattle. In addition to wild animals, other social activities can also have an influence in the form of fear and stress on cattle. This can be seen by the average value of FFS2 = 4.52 categories never, this is due to the location of the cages of most of the farmers far from residential areas so that human social activities do not affect the cattle.

Routine security monitoring and control at all times is so intense that the chances of outside interference are minimal. This is in line with the view of [12] that good housing environment management can prevent stress on livestock. This has an impact on the low handling of livestock experiencing stress, this can be seen with the FFS3 = 1.35 category never. The low number of cases experienced by farmers due to disturbance of wild animals or human activities, even if there are, will immediately be handled so that livestock do not experience stress for a long time and do not suffer economic losses. The low effort of farmers to reduce stress on cattle can be seen by the low average value of FFS4 = 1.15 in the never category. The lack of handling efforts due to preventive efforts or prevention by intensively maintaining livestock safety. This is evidenced by the high average value of FFS5 = 4.68 categories that have experienced fear so that cattle experience stress. The absence of protection to reduce

Region	Freedom from fear and stress							Total	Average
	FFS1	FFS2	FFS3	FFS4	FFS5	FFS6	FFS7		
East	4.30	4.40	2.20	1.60	4.30	2.10	1.20	20.10	2.87
West	4.75	4.38	1.00	1.00	5.00	1.00	1.38	18.50	2.64
North	4.70	4.70	1.00	1.00	4.70	1.00	1.00	18.10	2.59
South	4.20	4.60	1.20	1.00	4.70	1.00	1.00	17.70	2.53
Total	17.95	18.08	5.40	4.60	18.70	5.10	4.58	74.40	10.63
Average	4.49	4.52	1.35	1.15	4.68	1.28	1.14	18.60	2.66

Source: Primary data, processed 2021.
FFS1 = experienced attack/disruption by wild animals; FFS2 = experiencing stress due to disturbance from wild animals or other activities; FFS3 = experiencing fear to stress; FFS4 = never handle fear; FFS5 = how often do you experience fear; FFS6 = special protection; and FFS7 = stress treatment effort.

Table 7.
Freedom from fear and stress.

Region	Animal Needs Index					Total
	FHT	FDC	FPID	FENB	FFS	
East	3.19	3.00	3.81	2.87	3.65	**16.52**
West	3.02	2.38	3.71	2.64	2.59	**14.34**
North	3.04	2.59	3.70	2.59	3.20	**15.12**
South	3.14	2.72	3.85	2.53	3.05	**15.29**
Total	12.39	10.69	15.07	10.63	12.49	**61.27**
Average	3.10	2.67	3.77	2.66	3.12	**15.32**

Source: Primary data, processed 2021.
FHT = Freedom from hunger and thirst; FDC = Freedom from discomfort; FPID = Freedom from pain, injury and disease; FENB = Freedom to express natural behavior; FFS = Freedom from fear and stress.

Table 8.
Assessment of animal welfare level.

the fear of livestock to prevent stress can be seen by the low value of FFS6 = 1.28 in the none category. The absence of cases experienced by farmers caused no treatment carried out by farmers, this was seen by the average value of FFS7 = 1.14 in the category of none. Based on all components of the aspect of being free from fear and stress with an average value of FFS = 2.66, the category is quite good.

4.7 Comprehensive review of animal welfare level assessment

Based on the results of **Table 8** analysis for the five aspects of animal welfare in Sumbawa Regency with a total average score of 15.32, is in the almost prosperous category. The lack of welfare of cattle is caused by the level of knowledge and understanding of farmers, who are still lacking as a result of the absence of socialization or information received by farmers about animal welfare, only relying on hereditary experience in the cattle rearing system.

5. Conclusion and recommendation

Based on the results and discussion, it can be concluded that the value of the level of animal welfare or the welfare of Bali cattle with confined typology in Sumbawa Regency with a total ANI score of 15.32 is included in the almost prosperous category. The recommendation is that it is necessary to improve the aspect of being freedom from discomfort (FDC) and the aspect of being the freedom to express natural behavior (FENB) to improve animal welfare through increasing awareness and understanding of farmers and there needs to be government policy intervention in the context of implementing animal welfare in Sumbawa Regency as a efforts to increase the productivity of Bali cattle.

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Conflict of interest

We declare that there is no conflict of interest with financial, personal or other relationships with other parties or organizations related to the material discussed in this chapter.

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Section 8

Veterinary Tools

Chapter 9

Application of Conservation and Veterinary Tools in the Management of Stray Wildlife in Zambia

Lackson Chama, Grant Simuchimba, Kampinda Luaba, Stephen Syampungani, Jackson Katampi, Darius Phiri and Benjamin Mubemba

Abstract

In recent years, Zambia has seen an increase in the incidences of conflicts involving stray wild animals with humans. Notable among these animals include the African elephants, buffalo and lion. Consequently, this triggers a response from law enforcement units of both government and the department of national parks to control the animals. Regrettably, most of their responses have involved the shooting down of these animals, rather than taking advantage of conservation and veterinary tools to relocate the animals back into protected areas, and this raises concerns about the welfare of these animals. Therefore, this chapter will bring to light some of the locally available tools that could be used to control stray wildlife in order to contribute towards both conservation and reducing human-wildlife conflicts in Zambia.

Keywords: stray wild animals, human-wildlife conflicts, conservation, law enforcement

1. Introduction

Encounters between humans and stray wild animals have increasingly become a common phenomenon across Zambia. Although most of these developments are largely driven by routine animal migrations [1, 2], humans have been quick to connote such wildlife as "stray animals". Quite often, the presence of stray animals within the vicinity of human settlements triggers a response from government law enforcement units (that also include the department of national parks) to manage the situations. Depending on the reaction of the animals concerned, sometimes such responses (from law enforcement units) may involve the shooting down of these animals, rather than taking advantage of conservation and veterinary tools to give them space or relocate the animals back into protected areas. Consequently, this raises concerns about the conservation of these animals. In this chapter the authors discuss animal migrations and some of the key reasons why they occur. Further, the authors discuss some conservation and veterinary measures that could be applied to address potential human conflicts with stray wildlife, which they believe are applicable to the Zambian situation.

2. Animal migrations: why do they occur?

Animal migration is an important ecological process that has, for thousands of years, been critical in shaping the fitness of organisms across the animal kingdom [2–5], from the tiniest insects to the gargantuan blue whale (*Balaenoptera musculus*). Animal migrations also contributes towards the recovery of ecosystems, i.e. as animals moves to other areas, it reduces ecological impacts that could result from overgrazing in some ecosystems. Migrations occur seasonally and involves a return journey, making it different from other types of animal movement such as emigration when animals travel to find a new habitat to live permanently. Many animal species migrate, among which include species of fish, crustaceans, amphibians, reptiles, insects, and mammals. Animals can move either by land, sea, or air to reach their destination, sometimes crossing vast distances i.e. either in small or large numbers. The distances of migrations vary from species to species, i.e. from shortest (0.3 km) by the Blue grouse (*Dendragapus obscurus*), to the world's record longest (97,000 km) distance by the Arctic terns (*Sterna paradisaea*). Thus, animal migrations occur nearly across all countries on the planet, including Zambia, a landlocked country located on the northern franks of southern Africa. The country is endowed with a rich biological resource base, among which include 857 species of birds, 240 species of mammals, 153 species of reptiles, more than 90 species of amphibians. Some of these animals have been observed to migrate across regions and habitats from time to time. For example, several species of mammals in the country have been shown to exhibit a migratory behavior. Among these include elephant (*Loxodonta Africana*), lion (*Panthera leo*), hyena (*Crocuta crocuta*), wild dog (*Lycaon pictus*), cheetah (*Acinonyx jubatus*), lechwe (*Kobus leche*), tsessebe (*Damaliscus lunatus lunatus*), wildebeest (*Connochaetes taurinus*) and zebra (*Equus spp*). Animals migrate for several reasons, among which include the need to (1) search for food, (2) reproduce and gene transfer, (3) escape unfavorable weather conditions, (4) escape predation, and (5) find new territory.

2.1 Searching for food resources

Food is a very critical component of wildlife management as it defines the ultimate survival of animals across habitats. Animals need food to obtain the energy they need to perform various functions that define their fitness (e.g., reproduction, escaping predators, hunting, etc.) and also accrue nutrients such as vitamins and minerals that are important to maintain their health needs (e.g., disease resistance; [6]). Therefore, the need for food in animals is driven not only by the quantity, but also the quality of food available in their habitat throughout the year [7]. If the quantity of food is lacking, the animal may die of starvation, while a lack of quality may result in malnutrition. Generally, animal nutrition defines birth and death rates and is thus important in the overall survival of any wild animal population [8]. For example, animals that have adequate food and proper nutrition throughout their life circle have been shown to grow larger whilst at the same time remaining healthier than animals that experience poor nutrition [6]. Generally, animals with access to high quality diets are also expected to be more active than those on a low-quality diet [8]. However, the availability of food across animal habitats have been shown to vary either over time (e.g., due to changes in seasons or climate related stressors such as drought, floods and wildfires) or in space (largely associated with geographic location of certain habitats; [9]). In this case, some animal habitats can exhibit abundant food resources during one season, but less so in other seasons. Alternatively, while some habitats can be endowed with a diversity of food resources throughout the year, others could be in a critically short supply due to their geographical location. Such variations in food resources availability can drive the migration of resident animals from one habitat to another in search of food or limiting nutrients [7]. Consequently, such animals encounter human-dominated environments along the way, resulting into human-wildlife conflicts. For example, several heads of elephants have been observed migrating to search for food between Kafue-Mosi-Ou Tunya National Parks (in Zambia) and other national parks within four countries sharing borders with Zambia in the south-west, namely Angola, Botswana, Namibia and Zimbabwe [10]. The Blue Wildebeest (*Connochaetes taurinus*) which is found in Zambia's Liuwa Plains National Park is believed to migrate between the numerous pans following seasonal burns and flooding regimes within the broader Liuwa system in search of food resources. Beyond the borders of Zambia, several other animals (e.g., the Gray Whale, *Eschrichtius robostus* and the Great White Shark, *Carcharodon carcharias*) have been shown to migrate in search of food, suggesting the importance of food resources in shaping the survival of wild animals.

2.2 Reproduction and gene transfer

While some animals migrate to search for food, others migrate primarily to find safer habitats to reproduce. Reproduction is a particularly crucial component in the context of driving the fitness of animals, as it defines the multiplication and thus continuation of animal populations across ecosystems [11]. Inasmuch as reproduction can take place within the same population, some wild animals often prefer to breed with individuals from other populations. This process is important from the conservation perspective, as it prevents the incidences of genetic depression, resulting from possible inbreeding or breeding among animals that are closely related. A genetically deprived population is increasingly vulnerable to threats such as climate change, biological invasions and the spread of infectious diseases [12]. Consequently, this can undermine conservation efforts on such a population. In contrast, a genetically diverse population has enhanced fitness traits and will likely remain robust to extinction even in the face of such threats as highlighted above [13, 14]. Therefore, the need to maintain a genetically diverse population is what primarily drives some animal species to migrate in order to breed and thus exchange genes with individuals from other populations of similar species. Quite often however, animal populations that were once linked by a connected network of ecosystems, have over the years, been isolated due to the creation of protected areas that are predominantly isolated and the destruction of their migration corridors due to human land-use change. Therefore, as animals attempt to migrate from one protected area (PA) to another, they often encounter these human-dominated areas along the way, thereby resulting into human-wildlife conflicts. This is probably one of the major reasons as to why three lions were found within the human settlement area in the outskates of Lusaka in May 2022, and were later gunned down. The local public media (ZNBC) reported that the lions were potentially attempting to migrate between Lower Zambezi and Kafue National Parks.

Generally, Zambia is believed to have a genetically diverse lion populations across the Kafue, Zambezi and Luangwa ecosystems [15]. This diversity has been largely linked to the fact that individuals from different protected areas do migrate seasonally for breeding purpose, consequently facilitating gene exchange across populations. Ultimately, this increases the fitness of these populations to environmental threats. Besides the need for gene exchange, other animals migrate to locate safer habitats for producing and raising their young. For example, several species of birds, including the endangered Wattled and Crowned Cranes migrate into Zambia's Kafue and Busanga plains for breeding purposes. It is highly likely that these two ecosystems provide a safer and suitable environment for them to lay and hatch their eggs. Thus, any disruption caused on these habitats could potentially impact negatively on the breeding and population viability of these already endangered species.

2.3 Escaping unfavorable weather conditions

Weather is an important driver of species assemblages across biomes. Some species only exist in certain habitats because weather conditions (e.g., temperature, rainfall, wind, humidity, etc.) are optimal in the context of performing their routine ecological functions. When these conditions change, animals must adapt in order to survive in such environments. In an event that they cannot adapt, they need to migrate or else face extinction. Changes in weather conditions can either be a result of climate change or routine changes in seasons across a year. For example, Zambia has arguably two main seasons, namely dry (April to October) and wet (November to March). Change in seasons is often associated with altering ecological conditions across habitats, thus making the environment unfavorable for some animals [9]. Consequently, affected species are triggered to move or migrate across landscapes or regions in search of ecosystems with favorable weather conditions and only return to their native areas when conditions are back to normal. Several species of animals have been shown to migrate across landscapes and continents in search of favorable weather conditions. For example, the Eurasian reed warblers (*Acrocephalus scirpaceus*) are believed to migrate into Sub-Sahara Africa to escape harsh winter conditions in Europe, albeit they return to Europe at the onset of spring. Another bird that displays a similar behavior is the Red-breasted nuthatch (*Sitta canadensis*), which is normally resident in the northernmost parts of North America. During winter, it ditches its native habitat and migrates to southern regions of northern America [16]. Animals such as the Monarch butterfly (*Danaus plexippus*) have been shown to fly for over 4000 km escaping harsh winters in the US and Canada, to central Mexico where they hibernate. They would be in hibernation from October to early March when they commence their journey back because it would have begun to get warm in the US and Canada [17]. Besides migrating in search of breeding waters, the Blue and Humpback whales are other animals that have been shown to escape extreme weather conditions in deep oceans during winter by migrating to warmer waters near the equator [18]. However, they migrate back to their original habitats (the poles) during summer to feed. These are just a few examples of several other species of animals that migrate to escape unfavorable weather conditions. Although very little is documented about the migrations of Zambia's wildlife, this does not necessarily mean that our animals do not exhibit similar behaviors, to a certain extent, to those described in the examples highlighted above. Therefore, some of the animals often classified as stray animals, could be essentially attempting to escape unfavorable season-driven changes in weather conditions in some protected areas. Such weather driven migrations are likely to intensify in the face of changing climates and the projected alterations in temperature, precipitation and other climatic parameters. Thus, humans ought to be aware of the potential for climate change to escalate animal movements and this may involve crossing landscapes and anthropogenic barriers [15].

2.4 Escaping predation

The lifetime reproductive success of large ungulate herbivores and hence their life histories have been shown to be largely determined by predation risk [19–21]. Therefore, predation is an important ecological process, as it not only regulates the populations of prey, but also shapes the fitness of predatory animals across ecosystems. For prey animals, their goal is to avoid foraging or nesting in areas with high predator density and this could be achieved either at local, landscape or regional scales. Avoiding predation at local scale means prey animals adapt by developing fine-scale behavioral strategies to avoid or escape predation within, rather than outside the same ecosystem [22]. Escaping predation at landscape or regional scales implies that prey has to move outside their usual ecosystem and migrate for long-distances in search of areas that are safe, i.e. with little or no predators. This behavior involving long-distance, but temporal movement of animals to escape from predators is synonymous with migration [20, 23–25]. And research has shown that animals that migrate to avoid predation benefit by reducing predation risk and thereby allowing migratory populations to attain higher densities because of reduced mortality [20, 24]. The North American Elk (*Cervus elaphus*) has greatly benefited from migratory behavior that pushes it to areas that are near humans to escape predators such as gray wolves and bears [26, 27] that have often been shown to avoid human dominated areas. Similarly, some of the animals that have often found themselves in areas closer to humans in Zambia may have been driven to do so because of the need to find a new area for escaping predators in their native habitats. Therefore, instead of connoting them as stray animals and provoking them, humans should be trained to appreciate these ecological processes in order to help such animals find their way safely back into their designated habitats.

2.5 Finding new territory

Most animals often display a territoriality behavior where they constantly defend an area that is presumed to be their territory from intrusion. The defense of a territory could either be against conspecific or interspecific intruders. They often use agonistic behaviors or real physical aggression to defend their territories to ensure there is no competition for mating opportunities, access to limited resources and space for raising their young. Animals that fail to defend their territory can be dislodged, consequently losing their territory to competitors. Such animals could be forced to move in search of new sites to establish their territories. If the movement is permanent, then it is emigration, but if at some point (in the future) the animals decide to return to their old habitat to regain their territory, then it becomes a migration. This kind of behavior is common among several species of animals, notably among which include lions, leopard, cheetah, African wild dog and several species of ungulates. Lions have particularly been shown to be highly territorial, often occupying the same area for generations. Young male lions are forced to leave their mother pride by their fathers when they reach adult age to reduce competition for mating opportunities, and most importantly to avoid inbreeding as the young males can begin to mate their sisters if left to live within the same population. Therefore, the chased young males are forced to move in order to find a territory and start a pride or family of their own. Out of fear and desperation to find a territory, such animals can sometimes move or go beyond the boundaries of protected areas and consequently find themselves at conflict with humans.

3. Conservation and veterinary tools for managing stray wildlife

Several conservation and veterinary tools can be used to manage stray animals. Notably among those include (i) Community sensitization; (ii) Identifying and opening migration corridors; (iii) Managing PAs at landscape level; and (iv) Wildlife capture and translocation:

3.1 Community sensitization

The reactions that humans display towards stray wild animals (e.g., poisoning or shooting them down) strongly suggests a considerable lack of knowledge on what could be the key drivers of such animal movements. Certainly, people are correct to feel threatened, as some of these animals (especially lions and elephants) could potentially be aggressive and consequently life threatening towards humans. Except for the big cats, generally most wild animals are naturally peaceful and would rarely attack humans, unless provoked. Thus, when humans see these animals in their

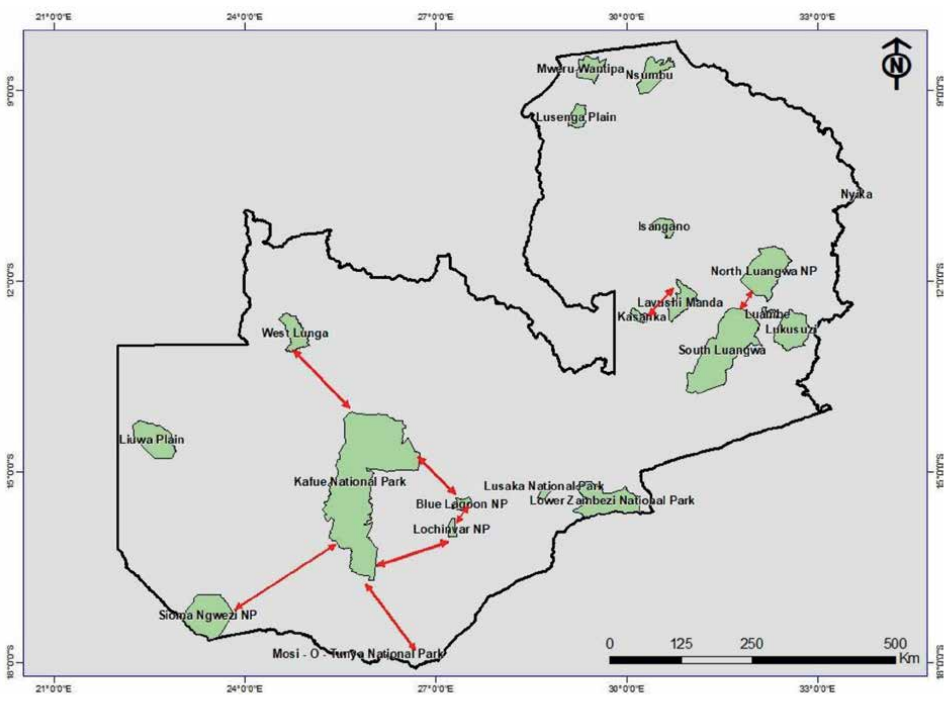

Figure 1.
Map showing wildlife migration corridors that occur across national parks in Zambia. In the figure, national parks are highlighted in green while the wildlife migration corridors are represented by red arrows linking selected national parks.

vicinity, they should be sensitized to restrain from provoking them. Animals such as elephants are quite aggressive if provoked, especially during mating or when moving with their young. Therefore, when humans see these animals, they should avoid teasing or bothering them; avoid escalating the situations into attacks by not staring the animals down or having direct eye contacts, as this is often seen as a challenge (by animals). Instead, people should back off slowly with emphasis on doing so slowly and quietly. Unless it has a baby, giving an animal space will likely move it to leave humans alone. However, if animals such as lions or other big cats launch an attack and consequently makes contact with humans, it is helpful to drop to the ground and play dead by covering the back of the neck with hands and the face with elbows. It is critical to play dead longer than expected, as getting up too early will catch the animal's interest again. Even then, it is important to realize that not all animals are peaceful, and that their reactions towards humans depends on the species and their mood at the time. To meaningfully address such situations, humans should be encouraged to immediately contact the department of national parks to report the encounter to facilitate the safe removal of the animal from the area. Overall, humans should be educated about some of the drivers of animal movements (e.g., those explained above) so that they can appreciate the need to stay out of their way. In Zambia, lessons can also be drawn from the communities that live within or across wildlife migration corridors. Several wildlife migration corridors occur between and across national parks in the country (e.g., the Kasanka-Lavushi Manda national parks migration corridors, the Kafue-West Lunga elephant migration corridor, the Sioma ngwezi-Kafue-Mosi-ou-Tunya national parks wildlife migration corridors, etc.; **Figure 1**). The fact that humans have continued to exist in these areas despite continued seasonal encounters with migratory wildlife suggests that the route towards coexistence is possible provided humans are trained on aspects of the key drivers of animal migratory behavior and how to react towards animals when they see them in their vicinity. Of course, measures should be put in place to ensure that such animals do not threaten human life and livelihoods (e.g., destroying their crops and livestock).

3.2 Identifying and opening migration corridors

Migration corridors save as pathways for wildlife to move across habitats and landscapes in search of food, mating partners or escaping unfriendly weather. Well protected migration corridors provide wildlife with relatively safe access to a diversity of habitat resources, which are typically dispersed across the landscape, albeit they may change with shifts in climate and seasons. Before humans dominated the earth's landscape, the vast majority of protected areas we have today were well connected by undisturbed animal migratory corridors. As a result, the majority of wild animals safely used these routes to move between protected areas, and did not encounter any human interference along the way. However, the majority of these corridors have since been transformed by anthropogenic activities and are currently dominated by features such as human settlements and crop fields. Over the years, however, animals have already marked these routes with cues such as pheromones which they are able to smell to find their way. Other animals use internal campus, mental maps (e.g., landmarks, such as rivers, trees, and mountains), the magnetic field of the Earth, as well as the position of heavenly features (e.g., the sun, moon, or stars) to help them navigate their way from one protected area to another. In fact, some animals are believed to have genetically inherited the migratory routes from their parents [28]. Therefore, even though humans have encroached on these migratory corridors, in the animals' mind, these routes still stand to-date (**Figure 1**). As a result, they will continue using them for generations to come. Consequently, human-wildlife encounters are unlikely to stop, unless humans identify these corridors and implement measures to either restore them or learn to temporarily coexist with wild animals during their annual or seasonal migrations. Therefore, research institutions and conservation agencies in Zambia should work in collaborations to identify potential migratory routes for wild animals across the country so that such areas could be considered for possible restoration to enhance for safe movement of animals. Besides, efforts should be made to tag some individuals among animals that exhibit a migratory behavior with trackers. Using trackers will be critical in helping to ascertain when these migrations commence and to therefore establish and mark the routes that animals take to move from one protected area to another. There is also need to establish if a wildlife migration corridor exists between Lower Zambezi and Kafue national parks (via Lusaka province), especially given the recent encounter between humans and lions in the area. Such information will be critical for designing monitoring and early warning systems to protect humans and wildlife, thereby averting human-wildlife conflicts.

3.3 Managing PAs at landscape level

Another way to address this problem is by managing protected areas using a landscape approach. Here, all protected areas (PAs) that share migratory animal routes should be managed as one block, rather than single and isolated ecosystems. Around the world, there has been an increasing shift from a PAs management system to the landscape approach in order to increase the resilience of populations of wild animals through the creation of transfrontier conservation areas (TFCAs). TFCAs increase opportunities for animals to not only find food resources and alternative mating partners, but also escape predation and harsh weather or climatic conditions. Effectively, this conservation approach gives animals uninterrupted access to migratory routes, consequently reducing the incidences of human-wildlife conflicts. Just within the SADC region, there are over 18 TFCAs that are in different stages of development. However, Zambia is only involved in two of these, namely the Zambia- Malawi TFCA and the Kavango-Zambezi (KAZA) TFCA (**Figure 2**). The Zambia Malawi TFCA includes Malawi's Nyika National Park, Vwaza Marsh Wildlife Reserve and Zambia's North Luangwa National Park, Nyika National Park, Lundazi Forest Reserve, Mitengi Forest Reserve, Mikuti Forest Reserve and the Musalangu Game Management Area. The KAZA-TFCA lies in the Kavango and Zambezi River basins where Angola, Botswana, Namibia, Zambia and Zimbabwe converge, covering 36 protected areas and several game reserves, forest reserves, game/wildlife management areas, and communal lands.

The establishment of these and many similar landscape protected areas are a major breakthrough in the context of promoting the conservation of migratory wildlife, whilst at the same time safeguarding livelihoods of people that live within these areas. For example, within the KAZA landscape, countries are promoting the establishment of community owned nature conservancies that have empowered communities with the opportunity to manage wildlife and wildlife-based enterprises (unpublished data). From these initiatives, communities can generate revenue to support their socio-economic well-being. Consequently, this increases people's appreciation and therefore participation in wildlife conservation. Countries should now begin to exploit opportunities for promoting the landscape approach for managing protected areas within rather than across borders, i.e. if doing so will contribute towards increased benefits for conservation and livelihoods for local communities.

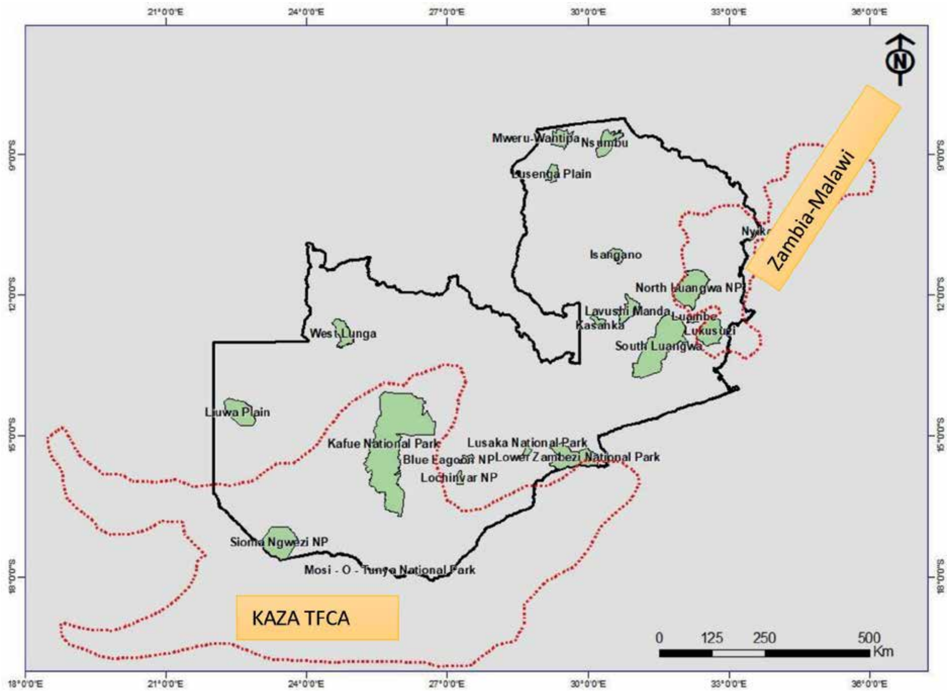

Figure 2.
On the map, highlighted in red dotted lines are national parks that are included in transfrontier conservation areas (TFCAs) to which Zambia is part, namely the Kavango-Zambezi (KAZA) and the Zambia-Malawi TFCAs. Please note that national parks from other countries, namely Angola, Botswana, Namibia and Zimbabwe as well as Malawi are not shown, but are all within the red-dotted line landscapes.

For example, Zambia has several national parks that exist in regional clusters, namely (1) Kasanka, Isangano and Lavushi manda national parks; (2) Blue lagoon, Kafue and Lochinvar national parks and (3) the Lusenga Plain, Mweru Wantipa and Nsumbu national parks (**Figure 3**). Clearly, these national parks are close to each other. Potentially, they used to be one ecosystem before humans established themselves across these lands. In this case, it is highly likely that animals still perceive them as one rather than isolated ecosystems. For this reason, migration and possible conflicts with humans is inevitable across these landscapes. Therefore, instead of managing them as single entities, conservation agencies should begin to advocate for the establishment of within-country models of TFCAs. The other parks that could be clustered include the Luambe, Lukusuzi and North Luangwa national parks. However, these are currently already part of the Zambia-Malawi TFCA (**Figure 2**).

3.4 Wildlife capture and translocation: taking advantage of veterinary principles

Translocation is a critical tool, often used in addressing challenges bordering not only on stray wildlife, but wildlife management in general. It is the deliberate capture, transporting and releasing of the captured wildlife into another ecological environment or back to their natural habitats in the case of stray wildlife [29]. Thus, it is a major wildlife management tool that can also be used in restocking or rewilding of depleted protected areas, including stocking of game ranches and zoos to assist in management of threatened native species [30].

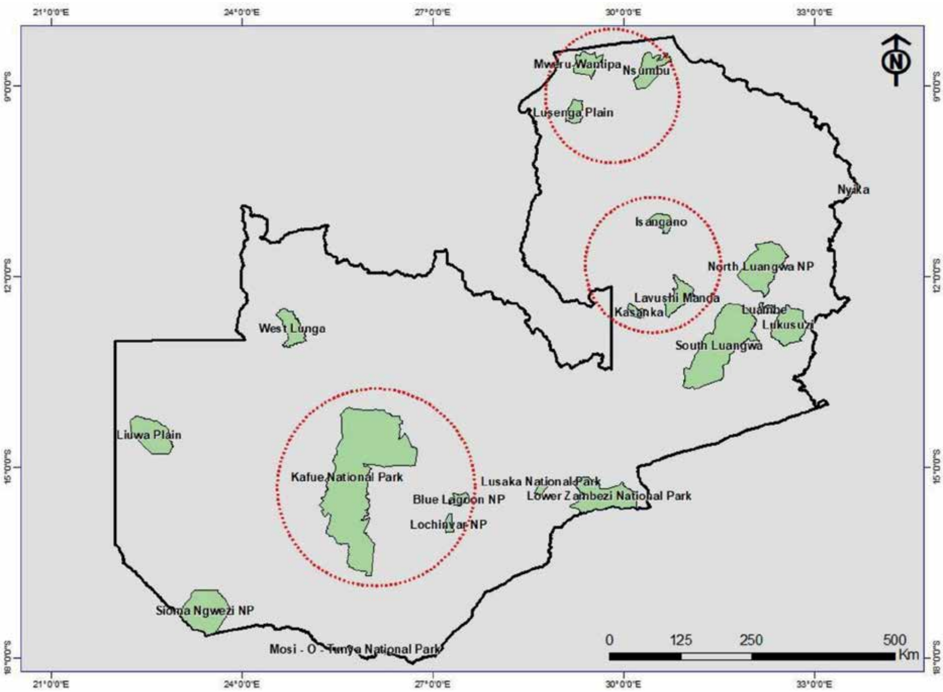

Figure 3.
Map showing protected areas that could potentially be clustered on one landscape within Zambia. Please note that the Kafue national park is currently part of the KAZA – TFCA. However, there is an option to also manage it on the same landscape as both blue lagoon and Lochinvar national parks given that the three parks are connected by the Kafue wetlands, a critically important wildlife migration corridor for animals such as lechwe, elephants and a diversity of waterfowl.

Capture and translocation of wildlife is a complex activity that involves a lot of planning by all participating staff, as the operation itself poses a high risk to both the animal and the personnel involved. A number of considerations have to be put in place before a decision to capture and translocate the animal is made. By Zambian law standard, at the center of these considerations is a competent and certified veterinarian who is to oversee the execution of the entire capture and translocation process [31]. In the case of stray wildlife, veterinarians are required to uphold and promote conservation values by capturing and translocating the animals to safety or their natural habitats. In Zambia, the wildlife management laws do not necessarily encourage a 'shooting down' approach for managing stray wildlife. Instead, conservation translocations are encouraged as an alternative mitigation measure to control the animals. However, capacity limitations often drive law enforcement units to resort to the 'shoot down' approach, especially where the animal involved threatens human life.

Capture and translocation of wildlife has a number of challenges which are unique depending on the species involved. To circumvent these challenges, adequate capacity, especially in the context of planning and assembling of expertise and equipment needed for the particular species is imperative to ensure rapid response and guarantee the safety of the animal or the local communities where the stray animal could be roaming. Thus, a decision would have to be made weather to control or translocate the animal depending on these circumstances. For instance, the team would require the services of a certified wildlife veterinarian, veterinary assistants, handling manpower and an appropriate transport vessel, large enough to move the immobilized animal.

However, the units responsible for managing these situations are poorly funded and this is a catalyst for ill preparedness. Consequently, this is what often leaves them with no option, but to control the animal as the only quickest and most feasible action, especially when lives of local communities are threatened. However, it is important to note that if the required skills and manpower are in place, the aspect of control is never an option.

3.4.1 Precaution during animal capture and translocation

During capture and translocations, different animal species require different equipment. For example, in cases of stray crocodiles, some of the required equipment include a well-designed trapping cage which has a bait inside. The bait will lure the crocodile and eventually have it trapped. For Lions, the bait is used to lure the animal to a place where the attending veterinarian can easily dart it, while in the case of elephants, buffaloes, rhino, etc., heavy duty craned trucks are needed for loading and transporting these animals.

For species that require darting as a way of immobilizing the animal prior to translocation (**Figure 4**), the operations are often conducted in accordance with the approved and conventional drug protocols. The execution of the operation is dependent on the terrain and proximity of the animal involved. Sometimes, however,

Figure 4.
A darted male lion being prepared for translocation.

it can be a challenge to execute this action, as some animals are aggressive and might not even come closer to a darting distance range. In this case, a helicopter could be employed especially for large herbivores. Once darted, it will take between 3 min to 15 min before the animal can be completely immobilized. During this period, the animal can run into any direction and might end up injuring itself and even die if the terrain is bad due to the effect of the immobilizing drugs. Hence, this makes planning as far as the choice of a darting and capturing site very critical.

In any case, capture and translocation is a traumatic experience that can cause stress on the animal. Common stressors include strange environments or habitats, sounds, smells which are usually not in their natural environment as well as high ambient temperatures. Due to stress and fear, the animal may attempt to escape. Effectively, this means that the carrying crate or container or trailer must be designed in such a way that it allows for good ventilation, but at the same time strong enough to comfortably hold the animal. Therefore, it is important that stresses are well managed throughout to ensure a smooth operation devoid of casualties.

4. Conclusions

Clearly, the incidences of human encounters with stray wildlife have increasingly become a common phenomenon across Zambia. And quite often, such encounters could result into the loss of human life or destruction of livelihoods. Alternatively, this could lead towards gunning the animals down, raising concerns for conservation. However, it is possible to address these human-wildlife conflicts provided appropriate measures are put in place especially to reduce human fatalities. The first step is to educate the public to appreciate some of the factors that drives animals to escape their natural habitats (e.g., protected areas) and move into human dominated areas. The public should appreciate that some animal species exhibit a migratory behavior, mainly propelled by several factors, among which include lack of food resources, the need to escape predation, the need to reproduce, escaping unfriendly weather, etc. Therefore, when they see them, they do not need to provoke, set traps or poison them. Instead, they should give them space to find their way. Most importantly, the public should report the sighting of such animals to the nearest office of the department of national parks and wildlife in their area so that experts can be mobilized to quickly address the situation.

We implore conservation and research institutions in the country to work in synergy to identify and undertake appropriate conservation measures that would help to significantly reduce the incidences of human encounters with stray wildlife. Actions such as the restoration of wildlife migration corridors, together with using a landscape conservation approach to manage animal ecosystems can contribute towards giving enough opportunities for animals to traverse across and potentially build a spirit of coexistence between humans and wildlife in the long-term. Further, it is critical for everyone involved to acknowledge that the department of national parks is better placed to help neutralize these situations, especially if the animal involved is in danger or threatens human life. In such situations, the department can help the animal through to the next destination either by directing it or taking advantage of veterinary tools to perform the capture and translocation procedures. This will keep the animals away from people.

In fact, it is important to note that if we are going to save human lives and conserve wildlife, capture and translocation still remains the best conservational tool in managing stray animals. This is especially critical today, given that cases of stray wildlife are on the rise. However, there is need to enhance the capacity of wildlife management units in the context of human resource and equipment or infrastructure to support the capture and translocation response activities. One approach to achieve this is to establish a task force on human-wildlife conflict mitigation within the government department responsible for wildlife management in the country. This taskforce should include the following personnel; personnel: a certified wildlife veterinarian, a wildlife police officer, a community representative, a honorary wildlife police office, among others. Further, the taskforce should be equipped or have access to the following equipment: a darting helicopter, crane truck, a reliable off-road vehicle, dart gun, hunting rifle, veterinary drugs and accessories, night spotlights, camping gears, different crates of different sizes, trailers and cages that are species specific among others. Such an arrangement will allow for easy and efficient deployment of the unit as and when their services are required. And because the incidences of human-wildlife conflicts are widespread across the country, it is cardinal that the operations of such a task force are decentralized so that each region or area is serviced accordingly.

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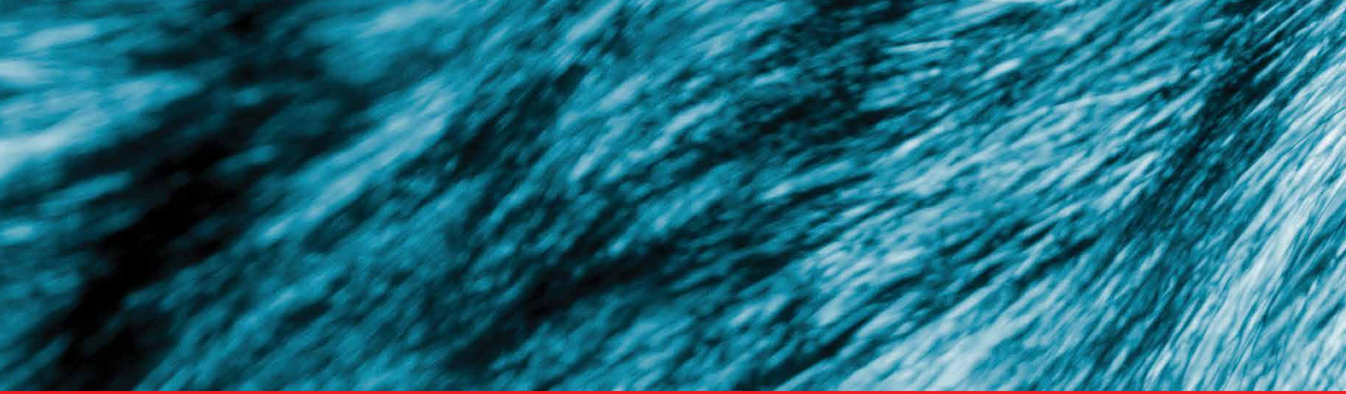

Edited by Shao-Wen Hung, Chia-Chi Chen, Chung-Lun Lu and Tseng-Ting Kao

Animal welfare has become a topic of serious discussion worldwide. Humane breeding has become an issue that has been given international attention in recent years. However, many people are still very unfamiliar with this concept. The foundation of humane feeding is based on AW. The main appeal is to allow animals to have five freedoms. When animal feeding meets these conditions, it can be regarded as meeting the basic requirements of humane feeding. The basis for the sustainable implementation of humane breeding is actually consumers. If consumers do not support the concept of humane feeding and do not agree with the price difference that should be paid for the production of humane products, then producers have no resources to put humane concepts into the production process. Therefore, only when consumers pay attention to humane production in terms of consumer behavior, more producers are willing to raise livestock and poultry in a humane way. As long as the insistence of both consumers and producers is satisfied, animals can be treated better.

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