Wild Animal Welfare Research Priorities
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Introduction

What is wild animal welfare science?

Wild animal welfare science is a developing field of basic and applied science that seeks to understand sentient wild animal's lived experience and quality of life.

Definitions:

**Sentience:** The ability to have subjective experience. Sentient organisms have the capacity for positive and negative mental states, such as enjoyment and boredom [1, 2].

**Welfare:** The valenced subjective experience of an individual over a given period of time (e.g. the entire lifetime or a defined shorter time period); the quality of an animal's life from their own perspective. Welfare is a mental property involving affective states, but is influenced by factors such as health, safety, environment, and nutrition.

Wild animal welfare science uses information and methods from animal welfare science, ecology, cognitive science, and other fields to understand the welfare of wild animals. While the field intersects with fields such as compassionate conservation and animal welfare science, it is fundamentally different from them in its focus on individual wild animals (rather than populations or biodiversity, as in the case of compassionate conservation). It aims to improve the lives of all wild animals (rather than those under direct human management, as in the case of traditional animal welfare science), irrespective of species affiliation or abundance.

Purposes of this document

The following is an annotated list of priority research areas important for advancing knowledge of animal welfare in the wild. Wild animal welfare is a relatively new scientific discipline that synthesizes and builds off of existing work in many other fields. This document presents critical research areas that the field needs to explore as a whole to determine the biology and ecology of welfare in the wild. As we learn more about critical knowledge gaps and identify which questions remain unanswered, this document will grow and change to reflect our understanding of the needs of the field. Although many research areas outlined here are aligned with our own mission, Wild Animal Initiative also considers several other factors, including scope, tractability, neglectedness, and relevance, for determining our internal research priorities and grant-making plans.
Who is this list for?

The list is primarily for researchers interested in developing a career in wild animal welfare science, or those seeking to understand how to leverage an existing research portfolio to support wild animal welfare science. This document should particularly help researchers who are interested in wild animal welfare but are not sure how to get involved, how their research fits in, or how to apply their existing skills to wild animal welfare. We hope the document also serves to demonstrate the diversity of disciplines relevant to wild animal welfare science.

The list is divided into three main sections:

1. Foundational Research: to understand what wild animal lives are like
2. Research Methods: how to monitor wild animals and measure their welfare
3. Interventions: understanding the actual or potential impacts of interventions aimed at improving wild animal welfare or for other purposes, such as population management or climate mitigation

How to use this document

We suggest experienced researchers use this document by finding their area(s) of expertise in the sections on Foundational Research and Research Methods, and reading some of the linked sources to understand how they can incorporate wild animal welfare science into their work. New researchers, or those wishing to change their area of expertise, might want to examine those two sections more broadly to find topics that strike their interest. Conservationists and managers might find the Interventions Section to be most useful when thinking about how their work intersects directly with wild animal welfare.

A note on sentience

To identify ways to improve wild animal welfare, we first need to understand what the subjective experiences of wild animals are like, and how they differ across individuals, populations, species, and environments. To clarify what wild animals’ lives are like, it is important to recognize the fundamental uncertainties involved with identifying sentience and inferring the subjective experiences of different animals. Since non-sentient organisms by definition do not experience the world, and therefore lack the capacity for welfare itself, we are specifically interested in what the lives of sentient wild animals are like. However, while ultimately knowing which organisms are sentient is crucial for improving wild animal welfare, determining which organisms are sentient is often difficult. This is especially so for the animal taxa with the most individuals, i.e. invertebrates.

While the scientific community generally agrees about the sentience of some animals, there is not yet total consensus about others — whether they are sentient, which types of subjective experiences they are capable of, or how sentience can be conclusively determined. Recognizing this, we operate and prioritize our work based on a few common assumptions related to the confidence that the scientific community has regarding the sentience of different species. For example, although there is sufficient evidence to infer that all adult mammals, birds, and reptiles are sentient [3], there is still debate regarding sentience of fish [4] and amphibians. There is, however, good evidence available to generally recognize these groups as sentient [4, 5], so at Wild Animal
Initiative, we operate with the premise that they are. On the other hand, the diversity within invertebrates and moreover among insects makes it harder to generalize. Nevertheless, all things being equal and without evidence to the contrary, we accept the possibility of sentience among insects and other invertebrate groups \[4, 6\]. We also acknowledge that there might be large differences among species within animal taxa.

Tractability is another important consideration with regard to prioritizing wild animal welfare research. The tractability of research on most invertebrates and the potential for feasible interventions that improve wild invertebrate lives in a known and quantifiable manner is much lower than that of other taxa, despite the potential to affect a large number of individual lives. But improving understanding of wild animal sentience is critical for the long-term success of wild animal welfare science as a field; thus we rely on others to produce sentience research that will help inform wild animal welfare research and prioritize actions. We consider the field of animal sentience research, which is deeply embedded in psychology and neuroscience, as a parallel discipline on which we rely, much the same as we rely on moral philosophy to frame our efforts.

Below we outline broad research areas that will help answer the question: “What are wild animals’ lives like?” While some of this research includes elements of the study of sentience, much of it can be accomplished using the current consensus on which species are sentient.

**Section 1: Foundational Research: What are wild animals’ lives like?**

This section aims to frame an individual's welfare in relation to biological and ecological processes, such as physiology, behavior, and population dynamics. To understand welfare in the wild, we need to know not only the welfare consequences of particular events, but also how much of a given animal's life those events make up. A relatively small welfare harm that occurs constantly may cumulatively be equally concerning as a large welfare harm that might only occur infrequently. Thus, understanding the daily activities of wild animals, and how they vary by ecosystem, species, and life stage, is a core component of wild animal welfare science.

Network dynamics resulting from the many interactions among individuals, communities, and ecosystems present a fascinating and challenging aspect of wild animal welfare science. Because they exist in a shared ecosystem, individuals affect the welfare of others through direct and indirect interactions. In turn, changes in the environment impact the interactions within these networks. There might be features of these networks and the ways they relate to the environment that tend to be either welfare-enhancing or welfare-reducing. In this section, we outline key research areas that will help build an understanding of the welfare consequences of individual experiences and how they relate to large-scale welfare patterns across ecological systems.
General Wild Animal Welfare

Seeking to understand wild animal welfare and sentence in the broader context

- How does individual sentence vary with development (ontogeny) and age?
- Do wild animals of different species on average live net positive or net negative lives? That is, what is the natural history of welfare for different species?
- What are the most important factors influencing the net welfare of the lives of individual wild animals?
- What constitutes positive experiences relevant to an individual's welfare and affective state?
- Do different species have different welfare capacities and how should those capacities impact human interactions with them?
- How is welfare affected by the ways that individuals, populations, and species interact with each other and their environment?
- How does past experience (e.g., during development) influence welfare in the present, and an individual's potential for positive or negative experiences?
- How do positive and negative valences and events interact to impact welfare?

Behavioral Ecology

Seeking to understand the relationship between behavior and individual welfare experiences

- What are the consequences of early-life experiences on the long-term behavior and welfare of wild animals? And do the impact of experiences accumulate over time?
- How do intraspecific interactions and conflicts of interest affect the welfare of individuals?
- How do individuals' welfare experiences determine the way they spend their time or energy in different ecological contexts to support their welfare and survival [e.g. 7–12], such as in relation to population density, predation risk, or habitat quality?
- How does an individual's welfare condition influence their interactions with their environment, and vice versa?
- How do different behaviors (e.g. migration vs. non-migration) differentially affect the welfare of wild animals?
- How does the environment's impact on welfare affect behavioral responses?
- How does personality influence welfare (and vice versa)?

Physiological Ecology

Seeking to understand the relationship between physiology and individual welfare experiences

- Which aspects of physiology are influenced by and have influence on welfare?
- How do positive and negative welfare influence physiology in the short- and long-term to impact health and survival?
- How does the physiological stress response interact with welfare?
  - Does the welfare impact of stressors vary by life stage? Which types of stressors impact welfare, and what is the direction of that impact?
How does accumulation of, habituation to, and sensitization to stressful conditions impact welfare?

**Disease Ecology**

Seeking to understand the relationship between disease and individual welfare experiences

- How do different diseases affect wild animals’ welfare?
- How does the subjective experience of disease differ among individuals?
- How does disease interact with other welfare threats and impairments (e.g. malnourishment, predation, injury)?
- How does welfare impact disease transmission by changing susceptibility or exposure to pathogens?
- How do different behaviors and demographic processes or parameters (e.g. dispersal, population density) affect disease risk and thus the welfare of wild animals?

**Population Ecology and Life History**

Seeking to understand the relationship between demographic processes, life history traits, environments, and welfare.

- How is individual welfare influenced by population density?
- How do causes of death vary within and among populations, and what are their welfare consequences?
- How does mortality rate vary in relation to demographic variables such as age and sex, and what are the welfare consequences of that variation?
- How do different demographic processes (e.g. dispersal, population density) affect animal welfare?
- How do life-history strategies and traits (e.g. parental care, age at maturity, sub-adult dispersal) shape the experiences and lifetime welfare of individuals within that species?
- Do different life-history strategies predispose individuals to greater positive or negative welfare experiences?

**Community Ecology**

Seeking to understand the welfare implications of conflicts and synergies among species as individuals seek to meet their needs.

- How does interspecific competition affect the welfare of individuals of each species?
- How do cooperation (mutualism) between species on an ecological or fitness level translate into welfare benefits and costs for individuals?
- What are the welfare impacts of parasitism?
- What are the consequences of trophic interactions (especially predator-prey dynamics) on population sizes and welfare of predator and prey populations?
- What are the welfare consequences of trophic cascades?
- What are the welfare effects of complex food web dynamics?
- What are the welfare impacts of keystone species on communities?
- How do interspecific interactions impact individual welfare?
Environmental Interactions and Landscape Ecology

Seeking to understand how individual welfare is impacted by their relationship with the ecosystem.

- How do changes in environmental conditions influence an individual’s welfare condition? Does the predictability of those changes affect their welfare impact?
- How do welfare experiences of individuals differ across space (landscapes and environments) and time (seasons)?

Phylogenetics

Framing welfare within a taxonomic context

- How does species relatedness affect our ability to predict welfare?
- How does life-history strategy (e.g. migration, fecundity, age at sexual maturity, and parental care) interact with phylogeny to increase or decrease welfare risk?
- How does frequency of different causes of death vary between species, and what is its impact on average welfare of the species?
- How do phylogeny and geography interact with relation to welfare?
- How does subjective experience vary across taxa?
- How does welfare relate to adaptation?

Climate Change

Predicting threats and opportunities to wild animal welfare that might emerge as a result of climate change

- How will climate change affect individuals’ welfare, directly (e.g. extreme weather) and indirectly (e.g. changes in habitat quality; coming into competition with other species)?
- How can individuals and species adapt — via dispersal, plasticity, or evolution — to changes in the environment? How will these adaptations affect their welfare and that of their offspring?
- How does welfare drive behavioral changes in response to climate change (e.g. change in migration), and are these behavioral changes successful in improving welfare and fitness within the changing environment?
- As species’ ranges change, how do new interactions between species affect the welfare of individuals of both species?

Molecular Ecology, Genetics, and Genomics

Seeking to understand individual welfare in the context of their genetics and genome

- How does an individual's genome frame their personality, development, and interaction with environmental factors, and result in their unique subjective experiences?
- What are the effects of genotypes or gene expression on the subjective experience of individuals and their welfare?
- What is the relationship between population genetic/genomic structure and welfare at individual, population, and species levels?
Evolution

*Seeking to understand how evolutionary processes (e.g. fitness) relate to individual welfare.*

- How do fitness and welfare expectancy outcomes compare in the context of evolutionary parent-offspring conflicts (i.e. adaptive behaviors for the parent limit fitness or welfare of offspring)?
- How does the drive for positive welfare influence animals’ fitness and populations’ evolution?
- How does subjective experience evolve, and what makes subjective experience adaptive or non-adaptive?

Human-Animal Interactions

*Seeking to understand welfare in relation to human-dominated landscapes*

- What are the welfare effects of human alterations to the environment that inadvertently affect wild animals? This includes effects of logging, habitat fragmentation, forest fires, pollution, hydrological disruption, lights, noise, and development of urban spaces and roads.
- What are the impacts of capture fisheries on wild fish welfare?
- What are the most humane wild animal management and capture methods?
- What are the costs and benefits of population control for wild animal welfare?
- How do urban environments affect wild animal welfare?
- How do human perceptions of wild animals affect the welfare and treatment of animals in nature? What role do human-animal interactions play in changing these perceptions?

Section 2: Research Methods: How can we measure wild animal welfare?

This section not only identifies some important methods and models that can be used to study wild animal welfare, but also indicates gaps in our understanding of methods. Research into the measurement of wild animal welfare will help to extend and validate existing welfare methods and metrics to free-ranging wild animals; identify measuring needs; define novel methods for understanding wild animal welfare; identify technologies that can be used to improve measurements of wild animal welfare; and identify metrics and indicators that can be systematically applied or adapted for many species. As researchers test welfare indicators and metrics, they will also establish whether there are species-related differences in how they need to be interpreted or applied.

**Definitions:**

**Indicators:** Measured variables that impact or are impacted by welfare, e.g. population density or glucocorticoid levels. These measures can be brought together into metrics or used alone to generate welfare scores. Not all indicators are equally valuable in evaluating welfare, and the feasibility and accuracy of different indicators vary significantly.
- **Whole-animal measures (a.k.a. whole animal profiling):** a single indicator that represents the entire quality of life of an individual animal [13].
- **Partial indicators (a.k.a. partial measures):** indicators that reveal only a single component of welfare, or a component’s cause or effect, e.g. a single emotion, environmental condition, or physiological measure that does not reflect the full welfare condition [13].

**Metrics:** Frameworks used to bring together partial indicators and output a single welfare score for each individual or population under study, e.g. the Five Domains Model, or Decision Support Systems.

- **(Non)Distressing methods:** Distressing methods cause disturbance to the wild animals under study in a way that might cause stress, decreased welfare, or potential injury, e.g. live trapping and handling. Distress can differ in degree: For example, rocket-netting deer is highly distressing, whereas behavioral observations of animals habituated to human presence is only slightly to minimally distressing. The use of non- or less distressing methods is highly recommended.

- **(Non)Invasive methods:** Invasive methods break the skin of the animal, e.g. blood draws. Invasiveness and level of distress are not necessarily aligned, as an invasive method does not have to be distressing in and of itself, nor are distressing methods always invasive. The use of both non-distressing and non-invasive methods is recommended, but where invasive methods are necessary, performing them non- or less distressingly is preferred.

*For example, invasive methods can be non-distressing, like placing medicinal leeches in a denning/nesting site to obtain blood samples for later collection [14]. Similarly, distressing methods are not always invasive, like trapping an animal to collect a hair sample or weigh them.

### Welfare Metrics [13]

*Potential frameworks that could be developed or adapted for wild animal welfare assessment. Although none of the frameworks below is ideal for understanding wild animal welfare, they provide a starting point for developing assessments and alternatives.*

- Applying the Five Domains Model [15] to wild animals [e.g. 16]
  - Originally developed for sentient animals used in research, teaching, and testing. Considers both environment and animal-based indicators (nutrition, physical environment, health, behavioral interactions) that lead to the animal's mental state, which is given a score based on the indicators. Has been recognized to have limitations especially for application to wild animals (see table below).
- Developing Decision Support Systems (DSS) for incorporating wild animals' welfare into wildlife management decisions
  - E.g. SOWEL [17] system originally developed for farm facilities. Provides a score for input housing/management practices based on a database of animals’ species-specific needs.
- Developing Welfare Quality®-like [18] systems for wild animal species
Originally developed for farm facilities. Considers animal-based indicators of welfare (physical comfort, appropriate feeding, good health, appropriate behavior) to give a score and indicate areas for improvement.

- Applying the Cumulative Pain Framework [19] to wild animals
  - This is an assessment of suffering (with pain defined as any negative affective state) rather than overall welfare, originally developed for farmed animals, but applicable to other animals.

- Applying Welfare-Adjusted Life Years (WALY) [20] to wild animals
  - Originally developed to compare welfare compromise of various diseases (or other causes) in companion animals by adjusting the Disability-Adjusted Life Year metric used for humans. Considers degree of welfare impairment during life and years of life lost to death from the same disease or cause, thus measures welfare expectancy, a prediction of welfare impairment for the remaining life of the individual.

<table>
<thead>
<tr>
<th>Metric Framework</th>
<th>Assessment level</th>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Five Domains</td>
<td>Individual</td>
<td>• Feasibility</td>
<td>• Non-cardinal scores: Welfare is given a letter grade, not quantified.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Provides detailed information on welfare conditions</td>
<td>• It’s possible to omit a relevant aspect of welfare, leading to an inaccurate and incomplete assessment of welfare</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Wide range of applicability</td>
<td>• Relies on observations only</td>
</tr>
<tr>
<td>Decision support systems (DSS)</td>
<td>Population</td>
<td>• Cardinal scores</td>
<td>• Environmental conditions that impact welfare are evaluated rather than animal welfare itself</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Transparent weightings designed to be updated as new information becomes available</td>
<td>• It’s possible to omit a relevant aspect of welfare, leading to an inaccurate and incomplete assessment of welfare</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Provides detailed information on welfare conditions</td>
<td>• Extensive data collection: lack of feasibility</td>
</tr>
<tr>
<td>Welfare Quality</td>
<td>Individual and population</td>
<td>• Cardinal scores</td>
<td>• It’s possible to omit a relevant aspect of welfare, leading to an inaccurate and incomplete assessment of welfare</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Animal-based assessment</td>
<td>• Extensive data collection is time consuming: lack of feasibility</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Provides detailed information on welfare conditions</td>
<td>• Weighting methods unclear, making validity questionable</td>
</tr>
<tr>
<td>Cumulative Pain Framework</td>
<td>Individual and population</td>
<td>• Cardinal measure (time in pain)</td>
<td>• Designed as a measure of suffering rather than full welfare, although positive experiences can be fed into the same metric</td>
</tr>
<tr>
<td>Welfare-Adjusted Life Years (WALY)</td>
<td>Individual welfare</td>
<td>• Cardinal measure</td>
<td>• Lifelong intensive data collection from multiple individuals, with the</td>
</tr>
</tbody>
</table>
| expectancy | | welfare impedance required before WALY can be applied to individuals newly experiencing the impedance  
- Designed as a measure of suffering rather than full welfare, although positive experiences can be fed into the same metric |

Based on the strengths and weaknesses of the above metrics, we believe that options for the development of metrics specific to wild animals would be fruitful. We recommend considering the following characteristics in their design:

- Universally adaptable, i.e. not species- or taxa-specific (though indicators will need to change by species, the categories of indicators should be applicable to all sentient wild animals).
- Accounts for both positive and negative experience, i.e. not exclusively suffering-focused.
- Relatively easy to implement (feasibility), preferably requiring only data that can be collected with minimal Distress to the animals.
- Application to individuals, but with the ability to scale to populations (i.e. ability to calculate a meaningful population average for welfare).
- Assesses welfare itself rather than welfare risk/potential. To do so, the majority of indicators must be animal-based rather than environmental, though some of the latter may be desirable.

**Welfare Indicators**

*Existing and novel welfare indicators with potential for use as welfare assessments. Partial measures can be fed into metrics frameworks (above), or otherwise used in combination with one another. Whole-animal measures can be used independently if they are validated. Novel indicators or indicators used in a species for the first time should be validated against existing welfare assessment techniques.*

**Condition-based welfare indicators**

*Identifying, improving, and validating condition-based assessments, and newly defining and developing them for wild animal species to enable rapid and large scale welfare assessment.*

- Body size and composition measures
  - Body fat percentage
  - Body mass changes\(^1\)
  - Mass-length ratios (snout-vent length, etc)
  - Body condition scoring
- Health and disease indicators
  - Integument (fur, feathers, scales, skin) condition evaluation
  - Parast size

\(^1\) Indicates a universal (or near universal) parameter, i.e. it should be applicable to invertebrates and vertebrates. We recommend using universal parameters when possible for comparative purposes. However, the feasibility, costs, and sensitivity should also be considered.
Presence of injury\(^2\)
- Disease indicators\(^2\)

**Behavioral indicators of welfare**

*Defining, developing, and validating behavioral indicators of wild animal welfare, with a specific focus on making quantitative assessments, defining species-specific metrics and indicators, and identifying ranges in responses.*

- **General behavior**
  - Activity levels
    - the balance of inactive and active behaviors\(^2\)
    - movement speed\(^2\) and gait
  - Interspecies interactions\(^2\)
  - Behavioral diversity\(^2\) (requires the ethogram of the studied species): behavioral complexity, variability, and flexibility \(^{[21]}\).
  - Qualitative Behavioral Assessment \(^{[13, 22]}\)\(^{2, 3}\)
- **Fear/alert behavior**
  - Vigilance levels
  - Flight initiation distance
  - Neophobia and neophilia
- **Species-specific behavior**
  - Social behaviors
  - Play behaviors
  - Vocalizations
  - Postures
  - Abnormal behaviors
- **Cognitive indicators\(^3\)**
  - Cognitive/judgment bias
  - Anticipatory behaviors
- **Discomfort behavioral indicators**
  - Sickness behaviors
  - Panting, sweating, fluffing, shivering, and other indicators of temperature discomfort

**Physiological indicators of welfare**

*Identifying, developing, and validating physiological welfare indicators in wild animals, including those specific for rapid assessment. (See our extended reference list of physiological indicators.)*

- **Glucocorticoids and their equivalent in invertebrates\(^4\)**

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\(^2\) Indicates a universal (or near universal) parameter, i.e. it should be applicable to invertebrates and vertebrates. We recommend using universal parameters when possible for comparative purposes. However, the feasibility, costs, and sensitivity should also be considered.

\(^3\) Indicates a whole-animal measure, i.e. one that represents the entirety of an animal’s welfare. We recommend using whole-animal measures when possible for ease of use and completeness. See Definitions for more information of whole-animal and partial indicators.

\(^4\) Non-invasive, time-integrated methods are recommended (e.g. fecal GC metabolites), because they monitor for chronic stress rather than temporary stressors. Additionally, stress responses should be used with caution to infer welfare, as the stress response indicates arousal more accurately than it indicates valence (positive/negative) of affect.
- Signaling molecules
  - Neurotransmitters
  - Hormones
  - Neurohormones (e.g. catecholamines, dopamine, oxytocin, adipokineic hormone, hyperglycemic hormone, etc. Might vary by taxonomic group.)
- Responses to the autonomic nervous system
  - Heart and breathing rates
  - Heart rate variability
  - Production of lactate used by the heart
- Metabolism
  - Metabolic rate
  - Energy mobilization (e.g. glycemia)
  - Lactatemia
  - O$_2$ transport
  - Body temperature
- Molecular and cellular processes
  - Heat shock response
  - Oxidative stress
  - Telomere length
  - Immune function, including bacterial killing, inflammation, leukocyte coping capacity, H(N):L ratio, acute phase proteins, phenoloxidase in insects
  - FKBP5 gene expression
  - DNA methylation
- Osmolality and acid-base balance
- Neuroimaging: while not feasible in the wild, images can support validation of other indicators

Positive welfare indicators

Identifying and validating positive welfare indicators (e.g. access to nutritious food) and their potential to complement negative indicators (e.g. having a wound). While many of the above indicators can indicate both positive and negative welfare, some are more specific to negative welfare (e.g. glucocorticoids), so having indicators that are specific to positive welfare can be useful in understanding the balance between them.

- Evaluating the presence, absence, or frequency of positive events (e.g. positive social encounters) as indicators of positive welfare
- Identifying and validating physiological and behavioral indicators of positive welfare, such as:
  - Play
  - Neophilia (i.e., inquisitive exploration rather than inspective exploration)
  - Affiliative behavior
  - Synchrony of group behavior
  - Oxytocin

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5 Indicates a universal (or near-universal) parameter, i.e. it should be applicable to invertebrates and vertebrates. We recommend using universal parameters when possible for comparative purposes. However, the feasibility, costs, and sensitivity also should be considered.
Environmental indicators of welfare

Identifying and validating environmental conditions that impact wild animal welfare and developing metrics for wild animal species to enable rapid and large scale welfare assessment.

- Presence, absence, and abundance of known stressors (e.g. predators, competitors, fights)
- Presence, absence, and abundance of resources (e.g. food, dens, habitats)
- Environmental variables that affect animal welfare (e.g. temperature, humidity, rainfall)
- Ecosystem variables that affect animal welfare (e.g. plant diversity or abundance, community diversity)

Selecting Indices and Metrics

- Assessing and comparing the level of distress caused by methods.
- Assessing and comparing cost-effectiveness of welfare indicators; for instance, by looking at the cost per measured animal for methods with comparable reliability.
- Assessing feasibility, validity, accuracy, precision, sensitivity, and cost-effectiveness of individual welfare indicators and combinations of indicators.
- Assessing whether fitness can be used as a metric or indicator of welfare under various circumstances.
- Determining what information or metrics are needed for informing decision-making by wildlife managers and other relevant stakeholders involved in wild animal-related management, interventions, or policymaking.
- Identifying keystone species or indicator species that can be used to represent the welfare of groups of species, ecotypes, or other relevant groups.
- Identifying how to select species-appropriate indicators and metrics, e.g. what species features make certain indicators/metrics appropriate or inappropriate, with preference for more universal approaches in order to compare studies and less distressing approaches to avoid negatively impacting welfare.

Methods for monitoring wild animals and their welfare

Identifying the most appropriate methods for continual assessment of welfare, how it varies with time and environmental conditions, and the least invasive ways to obtain such information.

- Evaluating animal monitoring systems in terms of reliability, cost, degree of distressing caused, and potential welfare impacts (e.g. satellite surveillance, camera traps, radio telemetry, biologgers, traps).
- Identifying, validating, calibrating, and expanding the use of less distressing methods for identifying and tracking individuals, such as motion-activated cameras, acoustic surveillance, eDNA, non-invasive molecular methods, alternatives to biologgers, and other innovative solutions.
- Exploring citizen science opportunities for remote monitoring of welfare.
- Use of biologging tools, such as accelerometers and heart rate monitors, to remotely monitor welfare indicators.
- Developing systems to monitor the varying welfare of individual animals throughout their lives as well as cumulative welfare over time.
- Identifying, validating, calibrating, and expanding the use of non-lethal, less invasive, or less distressing alternatives for monitoring welfare (e.g. use of hair, feathers, or eDNA to evaluate stress hormones or telomeres).
Modeling Welfare

*Developing theories of wild animal welfare, testing hypotheses using theoretical projection models, modeling potential scenarios and outcomes with predictive power, and empirically testing theoretical models with available data.*

- Using modeling approaches to predict and empirically test assumptions about welfare impacts, including the scale of negative to positive experiences, average wild animal life experience, and the welfare cost of death in relation to affective state.
- Using modeling approaches to predict and empirically test relationships between contributors to welfare and subjective experiences.
- Using systems and empirical modeling approaches to predict and better understand:
  - Relationships between demographic and environmental predictors such as, age, sex, habitat type, etc. and individual welfare.
  - The welfare impact of energy and time budgeting by individuals [e.g. 8–12].
  - Impacts of early-life behavior, choices, and provisioning on later life welfare.
  - Links between observed behaviors and physiology indicators and welfare, and specifically, how they relate to individual subjective experiences.
  - Welfare outcomes of variation in behavioral strategies (e.g. animal personalities).
  - Welfare consequences of interventions both for welfare improvement and other targets, such as climate change mitigation or biodiversity conservation.
  - Welfare consequences of natural pressures and disaster events, such as drought, fires, etc.
  - Expected welfare outcomes of disease, predicted climate changes, and other ecosystem variables.
- Modeling the welfare outcomes of concepts such as optimal population density, welfare expectancy, and life fates.
- Modeling interactions between *trophic dynamics* and welfare outcomes, including consumer-producer and predator-prey interactions.

**Section 3: Interventions: What can we do to improve the lives of wild animals?**

Ultimately, to improve the welfare of wild animals, management of wild animal populations will be needed. Therefore it is important to identify the most promising currently available methods, as well as to develop novel methods to steward nature in a way that improves wild animal welfare, while being cautious of the unknowns and making every effort to limit unintended negative consequences. To do this will require investigating the impacts of existing management approaches, as well as evaluating the potential of welfare approaches that are novel or yet to be trialed in the wild.

Converting knowledge gained from the study of wild animal welfare science into tangible interventions requires both applied research and the development of a community of practitioners who can apply the knowledge safely and effectively. Interventions for wild animal welfare would be best targeted selectively by dedicated
practitioners; however, management of wild animals currently occurs irrespective of an understanding of their welfare. Identifying how existing management can be more mindful of welfare considerations also represents an important and more immediate opportunity for improving wild animal lives. Therefore it is necessary to identify ways to incorporate into existing management approaches actions that can both mitigate negative welfare impacts and improve wild animal lives. Determining the least harmful and most beneficial methods for wild animal management is an important near-term goal of wild animal welfare research.

Studies that help define best practices for wild animal welfare interventions and norms for implementation are also essential to establish standards in the field of wild animal welfare science. It is important to approach the opportunity to convert knowledge to action with caution. Because animals interact with each other and their environment, most interventions will have indirect impacts from the target individual(s) to others. It is necessary to identify best-practice approaches when faced with uncertainty and balance urgency and caution to ensure that knowledge converted to practice does not do more harm than good.

Establishing best practices for wild animal welfare research and interventions

*Testing and evaluating practices for welfare interventions that minimize harms and unintended consequences*

Best practices in the study of wild animals

- Determining the effectiveness of the 3Rs principles for wild animal welfare research.
- Defining best practices for animal use while balancing information and impact of laboratory analysis, and identifying alternatives to animal use.
- Defining best practices for monitoring wild animals while balancing information and impact of surveillance.
- Identifying and reducing welfare impacts of captivity stress on temporarily captive wild animals (e.g. rehabilitation, translocation, temporary housing for research).
- Understanding and defining best practices for captive animals to be studied as models for their wild counterparts.

Best practice for wildlife interventions

- Defining best practices for operating under uncertainty.
- Defining best practices for monitoring impacts of interventions.
- Establishing adaptive processes for interventions.
- Assessing persistence and reversibility of interventions.
- Identifying the scientific evidence needed to inform decision makers (e.g. politicians and managers) with regard to wild animal welfare considerations.
- Understanding the welfare impacts and applications of Indigenous wildlife management and traditional strategies for interaction.
Human-animal interactions
The nearest-term interventions that might reasonably be accomplishable are those with the fewest system effects. Thus, changing the way humans interact with wild animals could represent the most impactful, tractable, and realizable way to improve the lives of wild animals in the short-term. In particular, identifying more humane ways to control populations, and reducing or improving the ways that wild animals are killed have the potential to improve the lives of many wild animals in the short-term. Therefore, while human-animal interactions are not a strong focus for Wild Animal Initiative, it is a priority area for others in the field of wild animal welfare research.

- Understanding the welfare impacts of fishing.
- Understanding the welfare impacts of hunting.
- Understanding the welfare impacts of supplemental feeding, e.g. bird feeders.
- Understanding the welfare impacts of land use and development on wild animals.
- Understanding the welfare impacts of sustainable development on wild animals.

Determining impacts of population control and other interventions
Although there are additional practical areas of relevance for interventions, practitioners are already actively engaged with wild animals in the areas of population control, disease control, rehabilitation, restoration, conservation, and climate change. These areas therefore represent (at least in the short-term) the most viable opportunities for interventions that are likely to be impactful. Identifying ways to address the welfare needs of wild animals, and improving practices for interventions in these areas, are important areas of research.

Welfare effects of population control
- Assessing welfare consequences of established wild animal control methods.
- Validating positive welfare effects of wildlife contraceptives.
- Developing non-lethal methods for population control of wild species, such as deer, foxes, badgers, and squirrels, and so-called ‘pest’ species such as rats and pigeons, and comparing welfare impacts among methods, such as wildlife contraceptives [26].
- Assessing welfare impacts among established methods for invertebrate population control and developing less distressing or less painful methods.

Welfare effects of interventions: climate change mitigation, ecosystem restoration, disease control, conservation, and rehabilitation
- Understanding welfare effects of interventions, including supplemental feeding, habitat provisioning, such as nest boxes, and population and environmental enhancements.
- Understanding the direct, indirect, and post-release welfare impacts of headstarting and reintroduction on target and non-target species.
- Studying post-release welfare of rehabilitated or captive-raised individuals.
- Determining the welfare impacts of translocations and assisted migration or range expansion on target species and on native animals.
● Understanding how management or interventions (including climate mitigation) to support one species affect the welfare of other species sharing the habitat.

● Understanding the welfare impacts of species conservation efforts (e.g. captive breeding, microhabitat management, etc.).

● Understanding welfare impacts of vaccine, parasite, and other disease control programs on target and non-target animals.

● Investigating welfare implications of Sterile Insect Technique (SIT) used for disease control, population control, and other interventions.

● Understanding welfare impacts of environmental enhancement (e.g. water quality improvements).

● Understanding how ecosystem restoration impacts the welfare of individuals living within restored environments.

● Investigating welfare effects of human-focused climate adaptation interventions that aim to reduce climate change impacts such as forest fires and flooding.

Conclusion

This Wild Animal Welfare Research Priorities document is intended to help researchers become aware of the most pressing questions impeding the ability to understand and improve the lives of wild animals. It also presents both the available methods for studying wild animal welfare and those that need to be developed or adapted.

Section 1 should help researchers explore which research avenues can be newly initiated or integrated into their current research. Section 2 should provide researchers with methods for measuring and monitoring wild animal welfare, and help identify those that need to be validated or evaluated for efficacy. Finally, Section 3 should help researchers, managers, conservationists, and other practitioners consider how we can positively impact wild animal welfare in the short term and build an understanding of the potential for even more effective intervention in the future.

The document highlights some of the remaining questions that need to be answered for us to have a long-term, broadly positive impact on wild animal welfare. As evident in the breadth of disciplines covered, wild animal welfare science is highly interdisciplinary. We hope that this document will both encourage and guide researchers who wish to integrate welfare into their work to seek out collaborations and funding to add a focus on welfare to their current research portfolio. Understanding welfare from the perspective of individual animals also has the potential to generate valuable insights into many of these related disciplines.

A PDF version of this document is available for download and off-line review. But it is intended to be a “living document” with continued updates and additions forthcoming, as new information is discovered. We will especially continue to enhance the linked resources, adding more explanations or expanded pieces over time. Thus we invite you to revisit this page and continue to explore the document regularly online as you continue your work in wild animal welfare.
Bibliography


