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Establishment and Implementation of an Animal Welfare Decision Tree to Evaluate the Welfare of Zoo Animals

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Abstract

During the last few decades, zoos and aquaria have made great improvements in their exhibit designs, feeding routines, social housing conditions, mixed species presentations, and environmental enrichment, as well as in the prevention of infectious and parasitic diseases, to enhance animal welfare. To monitor the effectiveness of all these changes, animal welfare science is needed. It is important to evaluate animal response by applying welfare metrics that include behaviour and/or physiology. To get a state-of-the-art overview of animal welfare metrics, Zoo Nuremberg organized a workshop in May 2016, inviting scientists from different disciplines. The workshop dealt with the challenges we face in developing and applying animal welfare indicators for zoo and aquarium animal species and clearly emphasized the need to assess the welfare of these animals. It was shown that animal welfare is science, and many scientific methods are available to assess welfare objectively at the species level, at least for some vertebrate species. However, it remains a challenge to apply different scientific methods for assessment of the broad species collection(s) of zoological parks and the huge number of individuals. The discussion also revealed that the assessment of animal welfare is a topic of much debate due to the complexity and practical implications of the evaluation. As a result, a written report was produced, *Assessment of Welfare of Marine Mammal Species in Zoological Parks* (Zoo Nuremburg, 2016), and a proposal for an animal welfare Decision Tree was created. The Decision Tree includes four different steps, involving keepers, veterinarians, biologists, and animal welfare inspectors:

1st Step: *Survey* – including life history, health protocol and nutrition plan, physical environment, animal management, and behavioural support system

2nd Step: *Theoretical Analysis* – including data analysis, data correlation, data evaluation, and preliminary report

3rd Step: *In Situ Inspection* – including verification of protocol application, and verification of management, observations, and hormonal analysis

4th Step: *Conclusive Report* – about the welfare state of the animals

This Decision Tree and its applicability were tested for two species at Zoo Nuremberg: (1) the bottlenose dolphin (*Tursiops truncatus*) and (2) the Antillean manatee (*Trichechus manatus manatus*). The results of the practical application of the evaluation are described in this article.

Key Words: animal welfare, animal welfare assessment, aquatic mammals, zoo animals, zoo inspection, Decision Tree, bottlenose dolphin, Antillean manatee

Introduction

High standards of animal welfare are vital for all animals and, therefore, for animal collections in zoological parks. Animal welfare is enforced by environmental legislation from the overarching European government collective (EU Council Directive 1999/22/EC) and by animal welfare legislation on the national level in many countries. A good welfare state is a prerequisite for justifying keeping animals under human care. Animal holders are responsible to secure animal welfare to the best of their ability. The last decade has shown that animal welfare can be measured, at least for some species, using different approaches. Still, monitoring animal welfare in zoos and aquaria remains a challenging task.

Two major problems arise when animal welfare is evaluated. The first problem is the lack of species-specific information regarding the general biology, behavioural needs, and cognitive potential of many species kept under human care. It is quite difficult to define animal needs when scientific data are not available. The second problem refers to the collection and interpretation of objective data (Broom, 2008), which makes it difficult to develop a general matrix with which animal welfare can be evaluated, especially if different classes of vertebrates are involved.

Regarding animal welfare monitoring, first attempts in Europe began in 2004 and were related to the evaluation of farm and production animals. The European Welfare Quality® (co-financed by the European Commission within the 6th Framework Programme; www.welfarequality.net) developed standardized ways of assessing animal welfare in farm animals. Certainly, one major innovation of the Welfare Quality® animal welfare assessment system is that it focuses more on animal-based measures (e.g., direct observations of animal body condition, health aspects, injuries, behaviour, etc.). Another project is AWin®; this is a project financed by the EU 7th Framework Program (FP7-KBBE-2010-4) that addresses animal welfare indicators in four distinct but complementary work packages. The overall objective is to develop animal welfare assessment protocols, including pain assessment protocols for sheep, goats, horses, donkeys, and turkeys. Even though both assessment protocols rely on animal-based measures, they still have difficulties as some of the measures only focus on the absence of negative welfare aspects (i.e., absence of prolonged hunger, thirst, injuries, and diseases) rather than identifying positive welfare indicators. Furthermore, these protocols are designed for the use within intensive animal farming, and, thus, direct applicability to zoo collections is rather poor.

Originally proposed as an animal welfare assessment tool for animals used in research programmes, Justice et al. (2017) adapted an animal welfare assessment grid (AWAG) for zoo animals. This AWAG was successfully adapted to evaluate two distinct taxonomic groups: (1) primates and (2) birds. The main advantage of this tool is that it is computer based and delivers an objective view of welfare. Even though this tool possesses advantages over the farm-animal protocol, it must still be conducted by experts or zoo staff and is mainly designed as an internal evaluation that a zoo can conduct on a regular basis. Another evaluation protocol focuses on marine mammals, particularly dolphins (Clegg et al., 2015). The C-Well® protocol includes different measures providing an objective view of animal welfare. Even though some measures need validation, the C-Well® assessment provides the first practicable framework to objectively evaluate the welfare of dolphins. However, like the AWAG, the C-Well® evaluation requires involvement of qualified zoo staff to conduct the monitoring.

In many countries, animal welfare monitoring has to be carried out by official inspectors (e.g., by the State Official Veterinary Department in Germany) who are specialized in animal welfare but not necessarily familiar with zoo species. A wide-ranging animal welfare evaluation matrix is urgently needed to enable authorities to judge the welfare state of zoo animals objectively.

Animal Welfare Science: Past and Present

The current animal welfare movement began some 50 years ago in Europe and goes back to the *Report of the Technical Committee to Enquire into the Welfare of Animals Kept Under Intensive Livestock Husbandry Systems* mandated by the UK's Minister of Agriculture, Fisheries and Food (Brambell & Technical Committee to Enquire into the Welfare of Animals kept under Intensive Livestock Husbandry Systems, 1965). The approach of this report became known as the *Five Freedoms*. However, within the last several years, it has become clear that the Five Freedoms required an update to be applicable to zoo animals. It needed to be based on current knowledge about varied species' biological processes, as well as provide an analysis that guides zoo managers more precisely while also giving a more comprehensive definition regarding the meaning of animal welfare (Mellor, 2016). Close examination of the Five Freedoms suggests that this approach does not necessarily encourage positive welfare but simply reflects a "neutral welfare state," even when applying the 12 criteria of Welfare Quality®. For example, meeting animals' basic survival needs as in the absence of prolonged hunger and thirst and the presence of comfort, health, and safety are considered a core requirement to secure the well-being of animals. While some of these requirements, such as provision of food, water, and health care, are indispensable prerequisites to secure life of animals under human care, others, like comfort and safety, are ambiguous and require further research, or at least clarification, to define optimal conditions under which animals should be kept. Also, Lund et al. (2006) added an ethical, economical, and political dimension to the scientific component with respect to animal welfare concerns and assessment.

Since becoming a concern ~40 years ago, the concept of animal welfare has experienced a wide spectrum of definitions and interpretations. It evolved from focusing primarily on the physical health of animals to recognising that animals possess cognitive potentials allowing them to experience positive and negative emotions. Today, it is widely accepted that animal welfare refers to a characteristic of a single animal and not to something provided to the animal by humans (Duncan, 1981). It means that to measure animal welfare objectively, a shift from a resource-based assessment—facilitated through the allocation of resources or aspects of management—to an animal-based assessment—through direct observation of the animal(s)—is needed (Whitham & Wielebnowski, 2013). Furthermore, it is also important to mention that an individual animal can experience welfare subjectively (Dawkins, 1990) and differently from other individuals of the same species experiencing the same physical conditions. Therefore, it is important to perceive an animal welfare assessment as a continuous process integrating the individual level into the evaluation.

Ethology played a key role in the development of animal welfare science (Millman et al., 2004) and provided important insights into the life of animals. A captive environment differs from the wild environment in many aspects—that is, lack of life-threating challenges by predators, diseases, and hunger; but also the complexity of the setting and the predictability of daily routines are often different between settings. Keeping animals under human care unsurprisingly restricts their behavioural repertoire; therefore, the study of behaviour is a critical measurement tool through which increased behavioural complexity and variability may echo, in general terms, an improved welfare condition for animals in human care when comparisons of behaviours in both settings yield similar results. Traditionally, behavioural studies concerned with animal welfare focused primarily on the detection of negative welfare states as, for example, frustration, increased stress, and abnormal behaviours (Fraser, 2008). However, in the last few years, more attention has been paid to positive welfare states—for example, attention, play, and anticipatory behaviour (Yeates & Main, 2008; Held & Špinka, 2011). Also, studies using preference tests have been conducted to assess what an animal prefers when given a choice; choice tests and operant tasks are two major procedures used to address preference and motivation in animals (Kirkden & Pajor, 2006).

Another field that is closely related to animal welfare measurement is endocrine physiology. The activation of the HPA (hypothalamic-pituitary-adrenal) axis and the release of glucocorticoids is certainly the most commonly used physiological measure of welfare. Researchers working with zoo animals use cortisol measurements for welfare evaluations (Cummings et al., 2007; Laws et al., 2007; Kelling, 2008). However, the interpretation of the results is quite ambiguous as some researchers clearly find low levels of cortisol when welfare is improved, and others find no relationship between cortisol levels and welfare status. As Maple & Perdue (2013) correctly remark, it is important to avoid using cortisol as a mono-causal measurement as it can be affected by many different variables.

Life history can also reflect a good or a poor welfare state. A widespread consensus is that good welfare, at the very least, means that the animals are free from diseases, injury, and malnutrition. It is evident that long-term stress and distress factors in a population are likely to produce pain, suffering, behavioural problems, and a greater susceptibility to diseases. These factors clearly affect life expectancy, lifespan, growth, survival, and general health. Longevity, reproductive success, and fitness can be expressed in numbers; however, even if we have a measurement, additional criteria and parameters are needed to draw a valid conclusion about welfare status. Nevertheless, life history is one core parameter in assessing animal welfare.

Over the last few years, the discussion about animal welfare has also incorporated the notion of cognitive "needs." According to Duncan & Petherick (1991), meeting the cognitive needs is the prerequisite to securing an animal's physical needs. To address how cognitive processes might be related to welfare, different paradigms have been applied. One paradigm involves cognitive bias, a relatively new approach that links operant response to ambiguous stimuli with animal emotion (Paul et al., 2005; Bateson & Matheson, 2007). For example, according to this paradigm, stimuli will be placed into a "more or less threatening" category to induce fear according to an individual's mental state. It can be assumed that such cognitive processes are expected to be evolutionarily adaptive as they help the animal to ascertain which situation to avoid or which to prefer. Even though the idea that animals experience emotions in the same way humans do is still debated, some authors suggest that some animal species share physiological and behavioural markers of emotions with humans and, therefore, it is likely that they experience emotions (Boissy et al., 2007; Panksepp, 2011; Leliveld et al., 2013).

Recent advances in the study of animal emotion (Bateson & Matheson, 2007; Mendl et al., 2009) have found that a limited set of cognitive processes are influenced by emotional states. Experiments using rats (Harding et al., 2004) or European starlings (Bateson & Matheson, 2007; Matheson et al., 2008) have successfully measured cognitive bias. In these experiments, animals are required to learn that one stimulus (CS+) predicts a positive outcome, whereas another stimulus (CS-) pertaining to the same sensory category predicts a less positive outcome or slight punishment. Once the animal learned this easy task, environmental conditions are altered either by enriching the environment or by making it unpredictable. Following this manipulation, the subjects are confronted with a novel stimuli intermediate between the two trained stimuli.

An optimistic cognitive bias is expressed by an increased tendency of the animals to classify the new stimuli as likely to predict reward. This was the case of animals that have been kept in an enriched environment, for example. Contrary to this, animals kept in an unpredictable environment showed a pessimistic cognitive bias as they classified the new stimuli, expecting a negative outcome. These experiments have shown that changing conditions influenced the mental states of the animals, which led to different responses. While current behavioural and physiological measures of welfare are dependent on the animal's response to a certain situation, cognitive bias studies may help to predict how the animal will respond or how far a certain situation may affect their mental state. It should be clarified, however, that a single animal response cannot be generalized to other conditions and/or to other individuals. Furthermore, even if cognitive bias studies proved to be an interesting approach to test the mental state of animals, welfare considerations arise as the experimental set-up might imply confronting the animals with excessively stressful situations.

In summary, there are several scientific methodologies available to assess animal welfare, and it is evident that they can and should be applied to zoo animals. The World Association of Zoos and Aquaria (WAZA) recognized the need of a strategy as a guide for zoos and aquaria to achieve high standards of animal welfare. With WAZA's *Caring for Wildlife* (Gusset et al., 2015), the zoo world received a holistic, science-based approach for animal welfare in zoo animals. This approach recognizes the fact that animal welfare is a multidimensional concept that is made up of different fields such as animal behaviour, endocrine physiology, life history, animal husbandry, and cognition.

The Animal Welfare Workshop in Nuremberg

In 2015, Nuremberg Zoo initiated consultations with different stakeholders that resulted in the organization of the first Workshop on Animal Welfare Indicators. The workshop followed one common goal: the establishment of welfare indicators applicable to one key species, the bottlenose dolphin (*Tursiops truncatus*), and the development of an easy-to-handle, functional Decision Tree for welfare evaluation.

The workshop was realized under the honorary presidency of MEP Dr. Pavel Poc on 3-5 May 2016 at Nuremberg Zoo. The meeting was hosted by the European Association for Aquatic Mammals (EAAM), the European Association for Zoos and Aquaria (EAZA), the Alliance of Marine Mammal Parks and Aquaria (AMMPA), the German Zoo Association (Verband der Zoologischen Gärten [VdZ]), the World Association of Zoos and Aquaria (WAZA), Europabüro of the City of Nuremberg, and Nuremberg Zoo. More than 80 people representing different institutions and organizations and diverse opinions regarding the pros and cons of animals under human care attended the symposium. The participating scientists and attendees' fields of expertise covered areas such as veterinary medicine, ethology, animal cognition, and zoo and wildlife biology.

The main conclusion of this workshop was to recognize that zoos and aquaria have made great improvements over the last decades in their exhibit designs, feeding routines, social housing conditions, mixed species presentations, and environmental enrichment, as well as in the prevention of infectious and parasitic diseases, to enhance animal welfare. However, the provision of all these inputs does not automatically imply good welfare for the animals. To control the effectiveness of all these changes, animal welfare science is needed. It is important to evaluate animal responses by applying welfare metrics that include behaviour and/or physiology. This workshop dealt with the challenges we face in developing and applying animal welfare indicators to zoo and aquarium animal species and clearly emphasized the need to assess the welfare of these animals. Animal welfare is science, and useful scientific methods are already available to assess welfare objectively at the species and individual levels. Nevertheless, the assessment of animal welfare is a topic of much debate due to its complexity.

Decision Tree

One main goal of the workshop was the development of a Decision Tree (DT) that incorporated all available measures that can be implemented by external inspectors within an animal welfare audit. The proposed DT is made up of different levels of data acquisition and analysis and consists of four steps: (1) survey, (2) theoretical analysis, (3) *in situ* inspection, and (4) conclusive report.

Practical Application

The audit at Nuremberg Zoo was carried out by the official state veterinarian and specialist in Animal Welfare in November 2016 who implemented the DT for the first time with bottlenose dolphins and Antillean manatees (*Trichechus manatus manatus*). At the start of the evaluation, ten bottlenose dolphins and two manatees were housed at Nuremberg Zoo (Table 1).

At the time of the inspection, the bottlenose dolphins inhabited a multi-pool system consisting of outdoor and indoor areas. The outdoor lagoon is made up of six pools of different sizes and depths holding 5.4 million litres of salt water. The indoor area has an additional three pools with 1.3 million litres of water. The total water surface is 1,800 m^2. The two Antillean manatees were housed in the manatee house, a tropical house with a pool (about 350 m^2 water surface area) with water depth between 0.5 and 4.5 m and a volume of 750,000 litres of fresh water.

The DT development began during the workshop and was finalized in October 2016. The first phase of implementation began in November 2016, and a revised version of the DT was finalized in December 2016. Results from the final evaluation made by the official state veterinarian were presented to Zoo Nuremberg in January 2017.

Implementation

The DT is a scheme for assessing animal welfare. During the first practical implementation, some modifications were made to render it more clear and accurate. The steps of the DT are presented as follows:

Step 1: Survey

The first step is a survey produced by the institution that consists of the life history, a health protocol, and a nutrition plan for the animals. This survey also includes information about the physical environment, animal management, and the behavioural support system.

Life History—This section includes life expectancy, longevity, mortality, survival rates, reproduction, and neonatal mortality for the species or group of animals in question. The life history of the population development should include data from the last 5 y. This gives an overview of reproduction parameters, animal ages, and social situations. To rate the screened population, it is important to provide life history data of other human-managed populations. For dolphins and manatees, data from the European Endangered Species Programme (EEP) can be used as reference. If available, comparable wild population data should also be taken into consideration.

Health Protocol & Nutrition Plan—The health protocol includes information on medical care and medical historical data for all individuals. The nutrition plan not only includes the amount and species of fish consumed, but also supplementation offered to the animals and an analysis of the fish they were fed. Both are indirect indicators of the degree of professional commitment and give the inspectors the chance for a pre-evaluation of animal management.

Physical Environment—This includes the pool structure and examines the life support system, water quality, noise level monitoring, provision of daylight and fresh air, etc. Regarding the physical

Table 1. Dolphins and manatees housed at Nuremberg Zoo; 1.0 = 1 male and 0.1 = 1 female.

Bottlenose dolphins (*Tursiops truncatus*)			
Sex	Name	Date of birth (d/mo/y)	Comment
1.0	Moby	1959 (wild born)	In Nuremberg since 1971
0.1	Anke	1983 (wild born)	In Nuremberg since 1991
0.1	Jenny	1987 (wild born)	In Nuremberg since 1991
0.1	Sunny	16/5/1999 (Soltau, Germany)	In Nuremberg since 2005
0.1	Donna	17/9/2007 (Duisburg, Germany)	In Nuremberg since 2014
0.1	Dolly	4/8/2007 (Duisburg, Germany)	In Nuremberg since 2014
0.1	Nami	31/10/2014 (Nuremberg, Germany)	
1.0	Noah	11/16/1993 (Nuremberg, Germany)	Left Nuremberg November 2016
1.0	Arnie	18/6/2000 (Soltau, Germany)	Left Nuremberg November 2016
1.0	Kai	21/8/2010 (Harderwijk, The Netherlands)	Left Nuremberg November 2016
Antillean manatees (*Trichechus manatus manatus*)			
Sex	Name	Date of birth (y)	Comment
0.1	Mara	1994 (Nuremberg, Germany)	
1.0	Zorro	2003 (Odense, Denmark)	In Nuremberg since 2009

environment, reference values recommended in the *Best Practice Guidelines* (EAZA/AZA), should be used to assess if a facility's values comply with these standards.

Animal Management—This section plays a crucial role in animal welfare and allows assessment of the following parameters: activity budgets, social structuring tools, enrichment, and training. Protocols should be available. Enrichment protocols have to include the way enrichment is being implemented and should reflect the actual notion of mental and physical stimulation. For enrichment, it is important to have a list of the different tools, but also a plan of how they should be applied, as well as an evaluation on the acceptance/use by the animals. Also, the different training schedules should be described and scored for every animal.

Behavioural Support System—The behavioural support system defines behavioural choices for mating, play, avoidance, coping, exploration, resting, comfort, and retreat. Whereas life history, health protocols, nutrition plans, physical environment, and animal management are straightforward and easy to describe and provide clear facts, the behavioural support system is more difficult to describe as it relies on the utilization of behavioural observation methods. These observations should be conducted by an objective observer who is familiar with the species behaviour but preferably independent of the facility (see Box 1).

All these data must be available to the official inspector. As all different aspects of the "animals' lives" are considered, many different people (e.g., trainers, veterinarians, curators, and researchers) need to work on the data. The data should be structured and clear so that the inspector is able to recognize details but get an overview at the same time. The compilation of all information can be very time-consuming, but the data are also very similar to information requested during the accreditation/inspection process (C-Well®, EAZA, and EAAM) by other organizations.

Adaptation/Modification of Step 1—After the first practical application of the DT, some minor modifications (Figure 1) were suggested by the inspector that were incorporated into the final scheme (Figure 2):

- The health protocols and the nutrition plan were extended by adding blood results and necropsy data.
- The animal management and behavioural support systems were unified because many aspects are related to each other.

Step 2: Theoretical Analysis by Official Veterinarian

The second step consists of the data review performed by the official inspector. Because of the large amount of data, the inspector needs enough time for review and correlation before providing a preliminary report. This review should give an overview first—for example, if the data provided meet the average value of the managed/EEP population and, for *Tursiops*, adhere to specification(s) of the EAAM guidelines. Data assessment and review may uncover potential concerns. High neonatal mortality, for example,

Box 1. Proposed behavioural sampling methods

Behavioural observations can be very time-consuming. Therefore, observations must be planned systematically to produce as much data as possible in a rather short period of time. It is recommended, based on experience from the first implementation at Nuremberg Zoo, that observations should be conducted on a regular basis for 15 d with observations done once per day over a 1-h or a 1.5-h period. Observations always have to take place between training sessions when the animals are under no stimulus control.

Scan sampling or instantaneous sampling seems the best method to examine dolphin and manatee behaviour for this assessment tool (Shane, 1990), with *scan intervals* between 2 and 3 min in duration. During the first observations, all ten bottlenose dolphins were housed at Nuremberg Zoo, which made it difficult to record every single behaviour for each dolphin. Thus, broad behavioural categories and social interactions were used to collect behavioural data on the dolphins. For manatee observations, with only two individuals present, every behaviour from each category could be recorded during scans. Thus, group size is a factor in what can be recorded and documented in these observation periods.

Using the *scan sampling* data, activity budgets were calculated for every individual. Overall percentage of every scan sampling category was calculated and used for comparison with other observation phases. Still, *scan sampling* often cannot detect single behaviours of special interest; therefore, to facilitate documentation of novel behaviors, *all occurrence* sampling was performed simultaneously to record behaviours such as aggression, stereotypic behaviour, breathing frequency, and regurgitation.

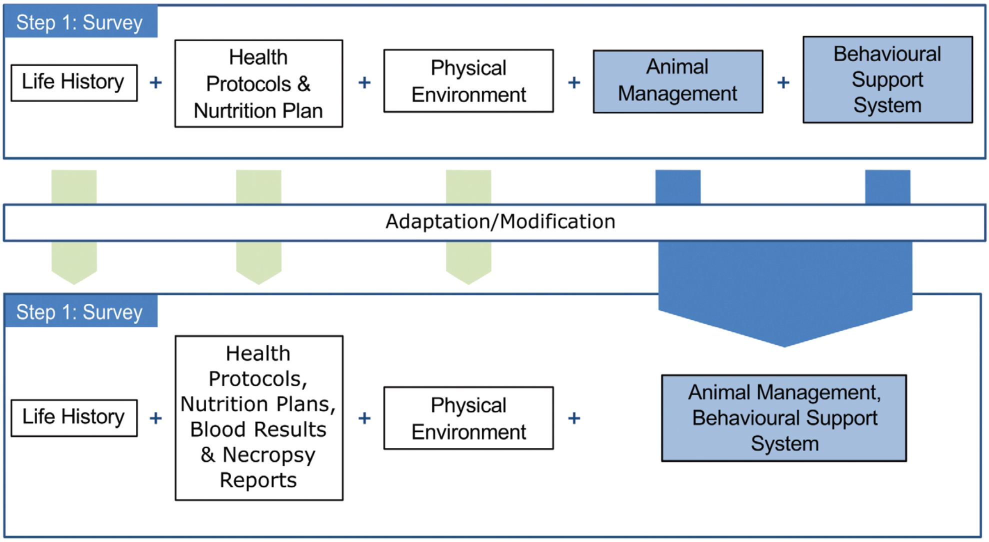

Figure 1. Minor modifications to the Decision Tree

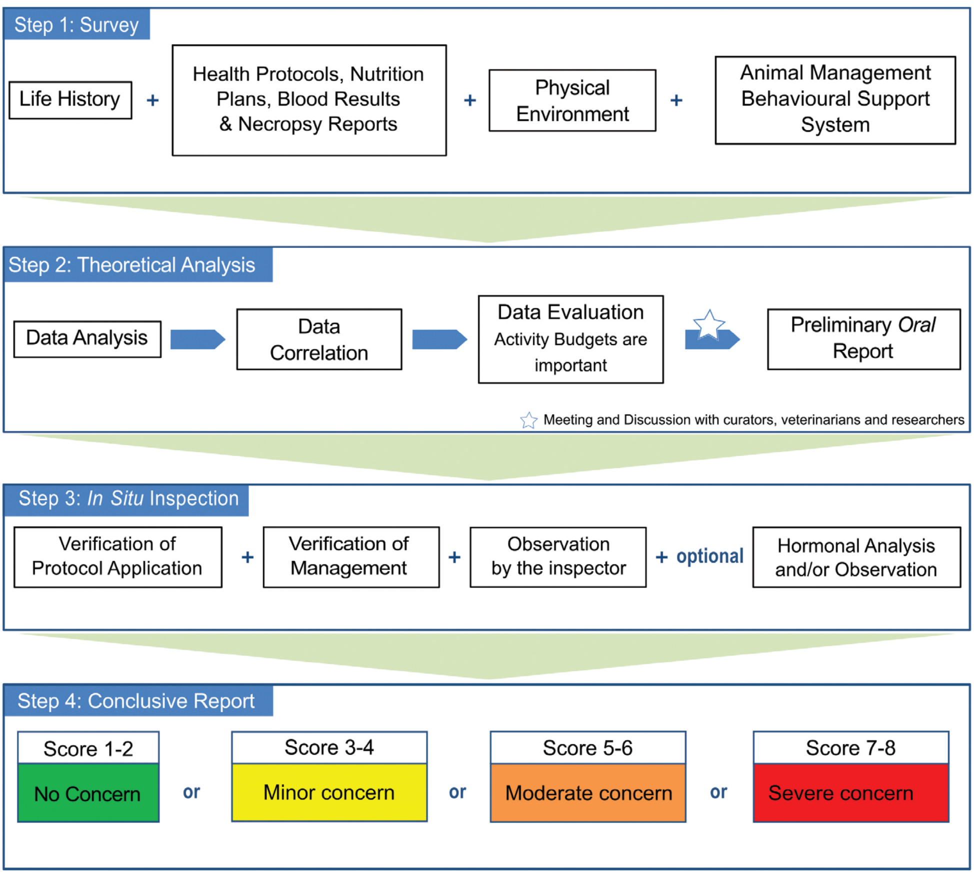

Figure 2. Final version of the Decision Tree

may be correlated with missing early intervention procedures or inexperienced mothers. Concerns need to be scored and identified as severe, moderate, minor, or no concerns and summarized in a preliminary report.

Adaptation/Modification of Step 2—Early during Step 2, it became obvious that some presets needed to be defined more precisely:

- Time frames were clarified. Medical data include at least 12 mo; and for special data like necropsy reports, 5 y are required.

- Ethological data turned out to be fundamental. The activity budgets are essential as an indicator of the welfare state of the individual animals in the group.

- Originally, a written preliminary report was postulated. The need for a report was changed to a meeting between the inspector and the responsible staff members. Findings are identified as problems, concerns, or nondetrimental findings.

Step 3: In Situ *Inspection – Zoo and Official Veterinarian*

In situ inspection is obligatory regardless of the findings in Step 2. During the inspection, the application of protocols and routine management is verified. Short observations on inspection day may raise questions and require additional hormonal analysis and/or further behavioural observations to clarify debatable findings. During inspection, selected protocols like the nutrition plan and health protocols are verified. The functionality of the technical equipment, life support system, food storage, and water chemistry must be checked. For verification of management, all responsible people must be available for structured interviews: keepers, technicians, curators, veterinarians, and directors/owners.

As mentioned previously, the most difficult part is judgement of behaviour. It might be difficult to recognize well-being or discomfort in a brief inspection situation; therefore, the scientifically valid behavioural observations described in Box 1 are necessary, and aspects like abnormal behaviours (stereotypies), human–animal interactions, animal–animal interactions, and hormonal analysis (stress and/or reproductive hormones in urine, blood, saliva, and faeces) may verify behavioural interpretation.

Adaptation/Modification of Step 3—During the inspection, it was concluded that in some cases it might be useful not only to request hormonal analysis, if available, but also to ask for further observation of the animals, focusing on special aspects such as behavioural abnormalities.

Step 4: Conclusive Report by Inspector

The conclusive report is written by the inspector after the *in situ* inspection and can yield four result categories:

1. If no concerns are identified, a good welfare status of the animals can be assumed, and the result refers to "best practice."

2. If there are minor concerns, acceptable welfare status of the animals is assumed, but improvements are recommended. Such a result is considered "standard."

3. Moderate concerns assume a doubtful welfare state of the animals and demand action in a defined time frame. These results are identified as "minimum standard."

4. Severe concerns assume an unacceptable welfare status of the animals. They demand immediate changes in an indisputable time frame. Such results are listed as "substandard."

Adaptation/Modification of Step 4—During practical application, scores from 1 to 8 were used to precisely quantify the findings. These scores should be used by the inspector starting from Step 1. The scores are calculated within defined categories:

- Documentation
- Technical equipment and life support system
- Nutrition
- Health
- Environment
- Management
- Behaviour and hormonal status

Each category can be scored separately leading to the following marks:

1-2 No concern
3-4 Minor concern
5-6 Moderate concern
7-8 Severe concern

Decision Tree Results at Nuremberg Zoo

During the inspection at Zoo Nuremberg, the inspector came to the following conclusions:

Bottlenose Dolphins

The inspector focused on social structure and contraceptive medication. In data from the zoo, the inspector noticed an unusually long separation of two dolphins; and in the medical reports, he noticed the use of a long-lasting contraceptive medication in sexually mature females. During the discussion, it was explained that the two separated animals were being prepared for an upcoming transport and, therefore, were already used to living apart from the rest of the group. The need for contraceptive medication was explained based on health problems of the two older females, which were not supposed to get pregnant for health reasons. As there was no further concern from the inspector and the results referred to best practice, no additional requests were made. The final score received was 1.5.

Antillean Manatees

Life history and the analysis of behavioural protocols showed some abnormalities in the female. Missing reproductive success could be explained by social and environmental changes during the last 6 y. Behavioural abnormality was identified as repetitive circling (50% of recorded behaviour) and reduced social contact. Therefore, additional observation was requested by the inspector. This concern lowered the overall good score of the manatee inspection to a score of 3.5, which refers to minor concern because of the female's behaviour. After a follow-up observation session, the decision was made to introduce another animal to the group to improve reproduction and possibly interrupt abnormal behaviour.

Discussion

Animal welfare is not only a scientific matter but also has legal and administrative implications. The proposed Decision Tree for animal welfare inspectors combines scientific know-how with legal needs to find a reliable, quantifiable, and comprehensible scheme for inspections. The proposed scheme combines data analysis with *in situ* assessment and, if needed, further animal welfare measurements can be requested/conducted.

The DT is based on the following assumptions: (1) the inspection must not rely on specialists in a specific animal species; (2) the dimensions and quality of datasets allow correlation between the information about the animals and their welfare state; (3) comparison with data from other populations of the same species allows identification of potential problems and concerns in the inspected population; and (4) communication between responsible staff and inspectors is essential for the process to be productive and positive.

Due to the complexity of the proposed DT, it is obvious that it can only be applied in selected cases and species. However, based on the DT structure, it can be adapted to any species of concern. The first implementation of the DT for dolphins and manatees showed that datasets from ethologists and veterinarians were sufficient to be reviewed objectively by the inspector, leading to a precise conclusion. The identified animal welfare concerns proved to be correct. To address animal welfare concerns in the manatee population, another male was integrated into the group; this did not result in a significant reduction of repetitive behaviour by the female manatee as was shown by further behavioural observations.

The DT proved successful for evaluating welfare aspects at the individual and group levels. The information required to run an animal welfare audit facilitates an objective view of the animals. Hormonal analyses are proposed to strengthen or refute findings from behavioural observations. Mostly reproductive and stress hormones are used for correlation of hormone status with behaviour (Cummings et al., 2007; Laws et al., 2007; Kelling, 2008). But even though many methods are available to test responses to stressors, for example, few physiological tests have yet been validated for consistent application to welfare questions. Methodical restrictions of these tests are widely underestimated.

Zoos and aquaria worldwide have a unique mission and a responsibility not only to provide a good quality of life to their animals but also to monitor to what extent this input is accepted by the animals. Because zoos and aquaria possess a wide spectrum of expertise regarding the management and general biology of their animals, they also must monitor their welfare by using updated scientific methodologies and data. Furthermore, zoos and aquaria are required to cooperate with authorities in providing their expertise when an animal welfare monitoring system must be designed and implemented.

One of the main challenges of the proposed DT remains the final aggregation of results from various steps that leads to a welfare score. Based on this study, it might be sufficient for some cases to use data provided by the institution to recognize severe concerns for one individual, a species, or a whole population. In other cases, it might be more productive to rely on direct behavioural observations to discover minor or moderate concerns. Thus, DT relies on relevant animal population data and incorporates current scientific methodologies of animal welfare measurements. As a "living document," it should undergo a continuous process of updating and revision while remaining applicable and quantifiable with respect to assessing animal welfare.

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