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Overall animal welfare reviewed. Part 2: Assessment tables and schemes

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Abstract

In the scientific literature several attempts have been made to systematically assess the overall welfare-status of animals in relation to housing and management. This paper reviews assessment tables and schemes that have been constructed to this end. These tables and schemes have a tabular format that allows an assessment of housing systems using a list of welfare-relevant attributes (properties of the housing system). Rather than identifying deficits, the focus of this review is on finding positive recommendations for the purpose of developing a method for overall welfare assessment (OWA) on a scientific basis. The main recommendation is to use the tabular format as representation formalism for OWA. The concept of linked tables provides the key to performing OWA on a scientific basis in an explicit and systematic way.

Keywords: assessment tables, model.

Introduction

Much has been written about assessment of animal welfare. The main focus has been either on showing that animals have a welfare status (e.g. Rollin, 1990) or on how scientific measurement(s) may say something about welfare (e.g. Broom & Johnson, 1993). These studies have generally stopped short of putting theory to practice. Relatively few publications exist where authors have actually attempted to perform overall welfare assessment (OWA), i.e. to give a quantified, 'objective' judgement about the overall welfare-status of animals in relation to housing conditions. What has been published hasn't received much attention, maybe because quantifying welfare is considered to be subjective and impossible. We are presently developing a method to perform OWA in an explicit and systematic way on the basis of scientific knowledge. In the previous paper (Bracke *et al.*, Part 1) we explained why we are optimistic and believe that scientific OWA is possible. In this paper we will review pa-

pers in which an attempt to perform OWA is made. We will focus on papers that contain assessment tables and schemes. The aim is to extract recommendations for further development of a procedure to perform OWA in a more objective way.

Overview of assessment tables and schemes

The literature on OWA is diverse. Some authors provide a practical assessment tool that can be applied on farms (Bartussek, 1986; Bock, 1990; Sundrum *et al.*, 1994; Beyer, 1998). Bartussek's TGI (Tiergerechtheitsindex) is even used in actual political decision-making in Austria (Bartussek, 1999). Other papers are more theoretical, containing only an attempt to provide a methodological framework for more objective assessment of animal welfare (Mellor & Reid, 1994; Taylor *et al.*, 1995; Baxter & Baxter, 1984). Most authors focus on one species, mainly poultry (Duncan, 1978; Brantas, 1981; Hurnik & Lehman, 1988; Hughes, 1990; Appleby & Hughes, 1991; Nilsson, 1997) and pigs (Baxter & Baxter, 1994; Anon., 1985, 1989; Schlichting & Smidt, 1989; Konerman & Van den Weghe, 1989; Svendsen & Svendsen, 1997). We also found papers on elephants (Kiley-Worthington, 1989) and pension horses (Beyer, 1998). Some publications cover more than one species (Sundrum *et al.*, 1994; Bartussek, 1986; Fraser, 1983). Others provide an assessment scheme for one type of housing system only (e.g. Nilsson, 1997, for hens in battery cages), or compare a number of specified housing systems for one category of animals (e.g. Brantas (1981), Hurnik & Lehman (1988) for laying hens; Svendsen & Svendsen (1997) for pregnant sows). Some focus only on behaviour (Brantas, 1981; Fraser, 1983; Schlichting & Smidt, 1989), while others include a wider range of attributes such as health, physiology and management (Duncan, 1978; Anon., 1985, 1989; Nilsson, 1997). Not all authors actually present overall scores; those which do present overall scores include Duncan (1978), Brantas (1981), Fraser (1983), Kiley-Worthington (1989), Bartussek (1986), Sundrum *et al.* (1994) and Beyer (1998). If possible, it would seem preferable to calculate overall scores, but it requires additional assumptions as to how overall scores may be obtained from component scores.

While all authors attempt to provide a biological basis for OWA, their approach differs. Some have a designer's background (Baxter & Baxter, 1984; Bartussek, 1986). Others use economical theories, especially cost-benefit analysis (Mellor & Reid, 1994; Taylor *et al.*, 1995) or derive principles from the social sciences that strongly emphasise the use of statistical evaluation (Beyer, 1998).

In the various papers on OWA two main formats can be distinguished: assessment schemes and assessment tables. First, we will explain the tabular format of tables and schemes, then we will give a few examples.

The formats are rather similar: they both specify welfare relevant attributes (Tables 1 and 2). They differ in that an assessment scheme is a generic tool that can be used for OWA, whereas an assessment table only illustrates OWA for a limited number of specified housing systems.

An assessment table (Table 1) is a matrix with welfare-relevant attributes specifying the rows of the matrix and housing systems specifying the columns. The cells of

Table 1. Format of an assessment table. The first column contains some examples of welfare relevant attributes. The other columns represent housing systems (HS). In this example each attribute score ranges over a scale from – to +. The overall-welfare score is some function of the attribute scores (e.g. sum or average; average in this example).

Attributes	HS1	HS2	HS3
Space	–	+/–	+
Climate	–	–	+
Abnormal behaviour	–	+	+
Etc.	...	...	...
Overall welfare:	–	+/–	+

the matrix contain scores per attribute for every housing system. An attribute score is often expressed in terms of plusses and minuses, but may also be a numerical value. The overall-welfare score of a housing system is derived from its attribute scores with the help of some calculation rule, e.g. summation or calculation of the (weighted) average score.

Assessment schemes have a rather similar format, but they can be applied to all housing systems for which the scheme was designed. As a result the matrix of an assessment scheme lacks columns with specified housing systems. A scheme is made up of a list of attributes, their levels (i.e. the possible values each attribute can take), their welfare-scores and a rule to calculate overall welfare from the attribute scores (Table 2).

In an assessment table Duncan (1978) compared the welfare status of laying hens in cages and pens with access to litter. He evaluated both systems with 9 items including health, physiology, behaviour, abnormal behaviour (feather pecking), management and production. Each item generates between 0 and 3 ticks, i.e. advantages,

Table 2. Format of an assessment scheme. The first two columns contain some examples of welfare relevant attributes and their levels. The last column contains attribute scores for every attribute level. In this table attribute 'space' has 3 levels; the other attributes have 2 levels. Per attribute the score ranges from – to +. Per attribute exactly one level is true for any given housing system. The overall-welfare score is some function of the attribute scores (e.g. average or sum). When an average calculation rule is chosen a housing system with $2m^2$/animal, natural ventilation and high levels of abnormal behaviour would receive an overall-welfare score of '–'.

Attribute	Levels	Attribute score
Space	2 m^2/animal	–
	3 m^2/animal	+/–
	4 m^2/animal	+
Climate	natural ventilation	–
	thermocontrolled	+
Abnormal behaviour	high levels	–
	no abnormal behaviour	+
Etc.	...	...

per housing system. He expressed overall welfare as the total number of advantages per system: 6 ticks for hens in cages and 8 for hens with access to litter.

During one year Brantas (1981) observed the behaviour of laying hens in three different housing systems: battery cages, litter with slats and get-away cages. Of the 37 behaviours that he considered relevant for welfare, Brantas ranked the means over the housing systems when they differed more than 10%. After explicitly excluding the use of additional weighting factors, he calculated rank totals, which showed that battery cages performed worse than either get-away cages or deep litter.

In an assessment table Schlichting & Smidt (1989) evaluated five different housing systems for fattening pigs using 10 items, which were assessed on a 5-point scale. The items were the main behaviour systems as well as the level of abnormal behaviour. Konerman & Van den Weghe (1989) quantified health and hygiene for the same housing systems. These two papers together will be referred to as the KTBL assessment in the remainder of this article.

Assessment schemes were produced by Sundrum *et al.* (1994) for various farm animals, which they call the TGI (Tiergerechtheitsindex, also called Animals Needs Index, Bartussek 1997) after Bartussek (1986). In these TGI schemes between 0 and 7 points are assigned to each of a number of specified attributes of a housing system. The TGI score is the overall sum of points, which has a maximum of 200 points. For example, for sows a pen size of more than 2,8 m^2/sow receives 7 points, but a pen size of 1,6 m^2/sow receives only 1 point. Other attributes include the number of floor types in the pen, access to pasture, trough width, nose rings and group size. In total 48 attributes are relevant for pregnant sows and these are organised into eight 'influence areas' (Einflussbereiche), which are movement, ingestion, social behaviour, rest, comfort/exploration, eliminative behaviour, hygiene and stockmanship.

The goal for OWA is to develop an assessment scheme. Application of this scheme to actual cases (housing systems) results in construction of an assessment table. Such a table is necessary for development and validation of an assessment scheme for OWA.

Terminology and other suggestions for standardisation

The various authors use different terms to identify and classify characteristics of housing systems that are relevant in OWA.

Generally used concepts to classify welfare relevant characteristics of housing systems are either needs (e.g. Baxter & Baxter, 1984; Hurnik & Lehman, 1988) or freedoms (Appleby & Hughes, 1991; Mellor & Reid, 1994; Webster, 1995). Bartussek (1986) and Sundrum *et al.* (1994) use the term 'influence area' and also 'functional area' (Functionskreis). We prefer to use the term needs. In our next paper we will explain why.

Concepts to identify characteristics of housing systems are more diverse. Several authors use the term 'indicators' (Fraser & Broom, 1990; Hughes, 1990). Taylor *et al.* (1995) use the term WRF (welfare relevant factor), which they define as 'all housing and management variables relevant to or indicative of [animal welfare]'

(Taylor *et al.,* 1995, p. 315). Beyer (1998) uses the term 'item' and Baxter & Baxter (1984) use the terms 'performance requirement', 'performance criteria', and 'performance specifications'. Also in use are the terms 'parameter' (Brantas, 1981), 'aspect' (Appleby & Hughes, 1991) and '(dis)advantages' (Duncan, 1978; Appleby & Hughes, 1991; Svendsen & Svendsen, 1997). The diversity of these terms is potentially confusing and further developments in the field of OWA would most certainly benefit from unified terminology.

We propose to use the term 'attribute'. This term is adopted from the literature on conjoint analysis, which is a statistical tool for multivariate data analysis (Hair *et al.,* 1995) to evaluate the quality of a product. The term 'attribute' has been applied in the context of welfare assessment by Den Ouden *et al.* (1997). An attribute is a housing characteristic, which may also be a characteristic of the animals, e.g. 'pen size' and 'production'. An attribute has two or more levels, which are properties of housing systems. For example, the level of the attribute 'pen size' may be '5 m^2'; the level of 'production' may be '24 piglets/sow/year'. For every housing system exactly one level is true per attribute. In addition, an attribute may, but need not be relevant for welfare. Whether or not this is the case is part of the welfare assessment procedure. When it is relevant for welfare it is assigned welfare value, which we will call 'attribute score'. From these attribute scores an overall-welfare score may be calculated.

Besides terminology, standardisation would also be welcomed in two further respects.

First, one scale should be used to present overall scores. Authors differ widely in how they present overall scores. For example, Fraser (1983) calculates the Behavioural Deprivation Index in percentages; Bartussek (1986) equates optimal welfare with 37 points; Sundrum *et al.* (1994) equate optimal welfare with 200 points. Since each scale can logically be transformed into a numerical scale, comparison between authors would improve when overall scores were expressed in a standardised way, e.g. on a scale from 0 to 10.

Secondly, constraints should be internal to an assessment scheme. Assessment schemes must set constraints that specify the class (domain) of housing systems for which they are designed. Constraints may concern the category of animals (e.g. Sundrum *et al.,* 1994) or the type of housing system; for example only battery cages (Nilsson, 1997). Constraints may be external or internal to the assessment procedure. An example of an external constraint is that legal constraints must be met before the evaluation scheme is used (e.g. Taylor *et al.,* 1995). The assessment schemes by Sundrum *et al.* (1994) contain the external constraints that housing systems with fully slatted floors and completely-outdoor systems are excluded, and that it is not allowed to calculate an overall score when the sum of points for one of the eight 'influence areas' is 0. By contrast, in Nilsson's scheme legal requirements have been incorporated in the list of attributes as constraints, i.e. as condemnation variables. When applying an assessment scheme, external constraints may be overlooked and, therefore, we recommend using constraints that are internal, i.e. incorporated into the list of attributes, because this prevents unintended misapplication of the tool.

Further evaluation of assessment tables and schemes

Below we will evaluate some further aspects of the assessment procedure. These are the quality of the output, calculation, weighing and scaling, and the list of welfare relevant attributes used to assess welfare.

Output of OWA

Constraints that restrict the application of the assessment tables and schemes to a specific category of animals or a specific set of housing systems, may help simplify the task of designing the assessment procedure. On the other hand, Fraser (1983) and Bartussek (1986) each present a scheme with application to a wider range of housing systems and species. This approach has intuitive appeal because it unifies the approach across species. However, this approach may also be limited in the ability to accommodate welfare requirements that are specific to certain categories of animals or to certain types of housing systems.

The value of the overall results depends, among other things, on the range of housing systems that has been assessed. Some authors only include a few housing systems (e.g. Duncan, 1978; Hurnik & Lehman, 1988). This reduces the value of the table, especially when the overall results also lie close together. With the exception of Duncan, authors who produced overall scores tended to generate clear distinctions between housing systems. Incorporation of a larger number of housing systems, especially when these differ widely with respect to both attributes and overall welfare, will improve the quality of the assessment. Beyer (1998) even statistically quantified the relationship between housing systems and welfare by calculating so-called z-values. A z-value of -1.5, for example, means that a score obtained for a housing system lies 1.5 standard deviations below the mean. Statistical analysis should be used in OWA, but it may be difficult to find a proper set of reference housing-systems to make this approach valid. Our point to include a wider range of housing systems in an assessment is not trivial. For, whereas the statement 'the welfare score is 7' is virtually meaningless, it becomes meaningful when it is situated in the context of a set of scores for different housing systems, which range, for example, from 3 to 10.

Several authors provide cut-off points or lines below which welfare is considered to be unacceptably low. Bartussek (1986) sets the level at 21 out of 37 points. Nilsson's scheme has politically-set % levels which increase over time. Fraser (1983) compared welfare across species and stated that a behavioural deprivation index of 25% results in aberrations in behaviour and that a 50% reduction is 'clearly stressful' (p. 16). Appleby & Hughes (1991) incorporated Duncan's idea (Duncan, 1978) of a welfare plateau into their assessment cube. They set this plateau at 2/3 of the sum of welfare value contributed by each of three equally important attributes, namely enrichment, group size and density.

Cut-off points have been criticised for being arbitrary and subjective (Mendl, 1991). Furthermore, the concept of a cut-off point is ambiguous. It may indicate the level at which the welfare status is (very) low or it may indicate the level at which

the welfare status is considered to be ethically unacceptable. Taken as an acceptability line the concept of a cut-off point falls outside the scope of OWA taken as a descriptive activity (Bracke *et al.*, Part 1). When taken in the first sense cut-off points establish distinct classes of welfare from what is actually a continuous variable that ranges from very good to very poor (e.g. Broom & Johnson, 1993). Using cut-off points in this way may be necessary for practical reasons. However, since such points are inherently arbitrary, we recommend that scientists abstain from drawing up such classes if possible.

Calculation, weighting and scaling

Whenever an overall score is calculated some calculation rule is employed to derive this score from the attribute scores. Constraints that specify, in the case of assessment schemes, when the scheme can be used to calculate welfare, have been discussed above. Two further aspects involved in calculation are weighting factors and interactions.

An interaction exists when the contribution of one attribute score to overall welfare depends on one or more other attribute-scores. In OWA interactions may be the rule, rather than the exception. For example, in pigs the value of a wallowing pool depends on the environmental temperature and the value of rooting substrate depends on the feeding regime. In the papers reviewed here we have found no apparent suggestions as to how interactions may be handled in OWA. Dealing with interactions remains an issue that requires further attention.

Some suggestions have been made with respect to the use of weighting factors. The constraints (see above) may include considerations of weighting. They may specify minimum requirements before a more quantified approach to welfare is deemed acceptable. Weighting factors varying between 3 and 10, are explicitly used in Nilsson's scheme. In the other papers weighting factors are set at 1, either explicitly (e.g. Brantas, 1981) or implicitly. Beyer (1998) points out that weightings are also affected by the number of items, i.e. attributes or rows in the table. She uses this strategy to increase the importance of roughage in her scheme (p. 39). Another example can be found in Kiley-Worthington (1989), who incorporates 4 different attributes (out of 14) about space, but only one for the combined attribute 'food, water and shelter'.

All authors who presented overall scores used additive calculation-rules: (weighted) component scores were added to determine the overall score. Other ways to calculate overall scores include using a multiplicative rule and using interpretative skills rather than calculation. For example, Mellor & Reid (1994), who did not calculate overall scores, proposed an assessment scheme in which the overall score is to be interpreted from a set of five component scores, which are the five freedoms. They suggest setting the overall score at least as low as the lowest component score. This suggestion is in accordance with certain intuitive reasoning about welfare (cf. Maslow, 1970). However, it may have counterintuitive implications when taken too far, e.g. when it were taken to imply that the most negative feeling ever experienced

by an animal would define its welfare status. Our main point here is that OWA may involve other than additive calculation rules.

Taylor *et al.* (1995) are sceptical about weighting and argue, instead, for an economic theory called Cost Benefit Dominance. This theory relies only on the ranking of housing systems within attributes. One housing system is better than another system when there is complete dominance of all attributes of that system over the alternative system. However, as Taylor *et al.* recognise, this theory runs into practical problems because systems will rarely be better in all aspects with respect to welfare. This is also confirmed by the other assessment schemes and tables reviewed here. Taylor *et al.* make several suggestions to solve this theoretical difficulty, but each of these reintroduces (aspects of) the weighting problem.

The ranking of levels within attributes is the basis of OWA (Brantas, 1981; Taylor *et al.,* 1995). It has substantially more objective validity than the consequent weighting and calculation of overall welfare. This ranking requires that attributes apply generally, i.e. across housing systems. It is because of this requirement, that the tabular format is especially suitable for OWA. All assessment tables and schemes reviewed here have a tabular format and employ only attributes that apply across housing systems. The attribute scale should range between the worst and best possible conditions within the constraints. This is made most concrete when the set of housing systems in the assessment table cover the full range for every attribute (as is done by Brantas, 1981, Hurnik & Lehman, 1988; Hughes, 1990). In any case it is helpful when the range is specified (e.g. that the scale ranges from 1, worst, to 5, best). Failure to do so (e.g. Duncan, 1978; Svendsen & Svendsen, 1997) complicates evaluation of the results. Furthermore, the scale should have a neutral mid-point, e.g. a 3-point scale or a 5-point scale. Beyer (1998) takes this one step too far. She requires that existing housing systems be distributed normally over the attribute scale. This makes welfare too relative. Although an assessment of welfare does depend on the range of levels the attributes can take (i.e. the domain of the assessment scheme), welfare does not depend on the number of housing systems that happen to have certain attributes (characteristics). A final remark about attribute scales is that they should only reflect local information about the attribute and its levels. Several authors also take into account considerations concerning the weighting of different attributes against each other and in relation to overall welfare. This is expressed in an assessment table or scheme in that for one attribute the scale ranges, for example, from – – to + and for another attribute it ranges from – to + + +. We suggest that such considerations should be specified explicitly in the calculation rule and in setting weighting factors, and not at the level of the attribute scores. The assessment of attributes should focus on the relationship between truth-values (what is true) and its scores related to welfare. For example, the assessment of the level of stereotypies should focus on how increases in stereotypies are evaluated on its own sub-scale. The reason why attribute scores should be set locally is that in an explicit assessment procedure every assumption should be open for criticism. The ranking of levels within attributes has a rather firm basis, whereas the weighting of attributes against one another is much more hypothetical. For this reason, considerations of weightings across attributes and concerning the calculation of overall scores should be formu-

lated as separate assumptions and not be mixed with assignment of attribute scores.

In assigning attribute scores authors of assessment tables generally were not explicit about the kind of scales they used, but authors of assessment schemes tended to use linear scales for the relation between truth-values and attribute scores (e.g. Beyer, 1998; Bartussek, 1986; Sundrum *et al.*, 1994; Nilsson, 1997). However, whether linear scales are appropriate remains to be shown.

Welfare relevant attributes describing housing systems

Attributes which are relevant for welfare include aspects of the environment, behaviour, health and physiology (Duncan, 1978; Hughes, 1990). The first aspect concerns design criteria; the latter three aspects are animal-based attributes, also called performance criteria (Baxter & Baxter, 1984; Rushen & de Passillé, 1992).

Beyer (1998) identified lying and feeding facilities, surrounding-building, stockmanship and outdoor exercise as relevant attributes for welfare assessment of pension horses using factor analysis. Although factor analysis can be a useful tool to find relationships between attributes, a risk associated with the use of factor analysis is that too much emphasis may be placed on contingent correlations at the expense of biological relations. By contrast, Bartussek (1986) classified environmental attributes according to the contact points with the animal: space, conspecifics, floors, air and stockmanship. Although his scheme lacks important resources such as food and water, it is, nevertheless, an interesting idea that relates to the concept of skin-lesions as a measure of welfare (cf. Ekesbo, 1981). Similarly, in Nilsson's scheme (1997) welfare is assessed according to three extending circles: the animal, the pen, the building (L. Keeling, personal communication). Such a logical ordering according to contact points between environment and animals, provided it retains the biological meaning of resources to the animal, seems a more reasonable way to organise environmental attributes.

Animal-based attributes can be ordered according to the types of response, which the animal has available to interact with the environment, namely behavioural and physiological. Physiology includes 'normal' physiology, which includes all states where homeostasis is maintained, and patho-physiology or pathology. Pathology can be organised hierarchically according to the specific diseases that have been described, which can be organised according to the main physiological systems involved, e.g. respiratory, urogenital, digestive, nervous, metabolic disorders. These same systems also organise the responses of 'normal' physiology. Production parameters are a subclass of physiological parameters that concern mainly aspects of metabolism and reproduction. Stress-physiology is a class of physiology that is particularly relevant for welfare. It concerns situations that involve attempts to cope with situations of reduced predictability and controllability. Stress-physiology may be regarded as an intermediate between 'normal' physiology and pathology.

Having a complete list of welfare-relevant attributes is a necessary condition for overall assessment, i.e. the attributes in a given assessment procedure must adequately cover all main fields of welfare. For this reason the health status, physiologi-

cal requirements such as respiration, osmoregulation, nutrition and thermoregulation, as well as behavioural opportunities are necessary components of welfare assessment. Several tables and schemes seem to meet this criterion, e.g. Mellor & Reid (1994), Hurnik & Lehman (1988), Nilsson (1997) and the KTBL assessment. For other authors this is less obvious. For example, Beyer (1998) and Sundrum *et al.* (1994) mainly focussed on design criteria for practical reasons and the extent such an approach allows adequate assessment of performance criteria is not easily answered.

In a full specification of an assessment table for OWA both truth-values and attribute scores should be given for every attribute. This requires a detailed description of every housing system. In some papers the systems were hardly described, but Svendsen & Svendsen (1997) included simple drawings of the pen-layout and the working group on pig housing (Anon., 1985, 1989) included pen-layouts together with a detailed table describing the systems. The tabular format has advantages for this purpose too, because it forces to be explicit and systematic.

A further advantage of using the tabular format may be realised when tables are linked as in a relational database (Date, 1995). Linked tables may allow making various sources of information available for welfare assessment. One table, in which housing systems are described, can be linked to the assessment table by the names of the housing systems. Similarly, the table for overall assessment can be linked to supporting tables by the attributes (e.g. Fraser, 1983; Sundrum *et al.*, 1994). Konerman & Van den Weghe (1989), who assess the health status in relation to housing systems for fattening pigs, also provide an illustration how this is done. Their final table contains three attributes: infection pressure, claws and limbs and (health) control. Each of these is assessed in a separate table. For example, (health) control is assessed in a separate table from the attributes group size, accessibility/reachability, building/unit size and (age) uniformity, and the overall results of this table are used as a component in the final table. In this way linked tables can support defining operational definitions of compound concepts.

Finally, tables may be linked to support formalising the relationship between welfare and its scientific basis. When scientific knowledge is collected in a table, attributes can provide the link to the assessment table. This is a very important feature, as it may support providing an explicit scientific basis for OWA. No paper reviewed here does this, and, as a result, the scientific basis remains exemplary and mostly unspecified. We conclude that linking of tables may support the construction of a formalised, i.e. explicit and systematic, procedure for OWA in all aspects of its problem space, namely the description of housing systems, welfare values and the scientific basis. Doing so within the framework of a relational database allows securing data integrity (Date, 1995) and it allows dealing with large amounts of data. This seems required for OWA, because welfare is a complex problem, which depends on many factors (Dawkins, 1997). In the papers discussed here, all tables and schemes are limited in size; the number of rows is maximally 48 (Fraser, 1983). Overall welfare assessment that aspires approaching the ideal of taking into account all available data (Duncan, 1978; Rushen & de Passillé, 1992), therefore may benefit from database technology.

Recommendations

In OWA an attempt is made to descriptively assess the overall welfare status of animals from what is known about their biology and about their living conditions, i.e. about attributes of the housing system in which they are kept. OWA involves a problem of multi-criteria decision making with fuzzy information. The main task for OWA is to increase the degree of objectivity involved in making overall-welfare judgements. The best way to do this is to make all steps between the attributes of the housing system and welfare explicit and perform them according to some systematic procedure. Only after the entire procedure has been made explicit will it be possible to criticise assumptions and systematically search for improvements. The tabular format seems to be a suitable tool for making OWA explicit and systematic (Webster, 1995). In this format housing systems (in columns) can be assessed in a systematic and analytic way according to a list of welfare relevant attributes (in rows). We have used this format successfully in representing the arguments pig experts use to explain their scores for welfare in relation to housing conditions (Bracke *et al.*, 1999).

Some minor recommendations include standardisation of terminology and scales. We suggest using the term 'attributes' and a scale between 0, worst and 10, best. Constraints should be specified and preferably be stated within the table to avoid erroneous application. On the other hand, cut-off points that specify what level of welfare is still acceptable, should not be given, because scientific OWA is a descriptive activity that is logically distinct from ethical assessment.

What is important for OWA is to specify the relations between welfare, housing and scientific knowledge.

The format of an assessment table focuses on the relation between welfare and designated housing systems. To develop a scheme for OWA an assessment table should be constructed which includes a number of housing systems that cover a wide range of animal environments. The assessment of these housing systems can provide useful reference scores to facilitate the interpretation of newly obtained scores for other housing systems.

Much work remains to be done concerning the weighting of attributes and calculation rules. So far, additive calculation rules that did not use additional weighting factors were used most often. The basis for calculation is the ranking of the levels within attributes. Therefore, in OWA the attributes should apply across housing systems and attribute (welfare) scores should be assigned from a local perspective, i.e. without taking into account considerations concerning the weighting between attributes. The weighting of attributes and the calculation rule, which is needed to calculate overall welfare from attribute scores, should be specified separately. Because weighting is more problematic than the ranking within attributes, sub-scores should be retained and presented in addition to the overall scores.

The relationship between attribute scores and descriptive properties of the housing systems should be made explicit. This may be done by providing a full description of the housing systems, including, for example, drawings of the pen-layout, as well as by linking tables. Linked tables, as in a relational database, may also support assessment of compound attributes and support assessment on an explicit scientific basis.

Database technology also allows that many attributes are taken into account. However, some logical and/or biological ordering principle is needed to ensure that welfare is assessed overall, that welfare is assessed on an objective and scientific basis while retaining the idea that the point of view of the animals is definitive of its welfare status. How this can be done will be discussed in our next paper.

The main conclusion of this paper is that the tabular format and the concept of linked tables are necessary to solve the main difficulty in OWA, namely to evaluate overall welfare in a procedural and explicit way that is open for criticism and, most importantly, allows further improvement.

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