

Methodology for deriving non-market trait values in animal breeding goals for sustainable production systems

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Abstract

An important aspect of the term sustainability is that environmental, genetic diversity, ethical and social aspects should be accounted for in addition to short and long-term economic value. The need for long-term biologically, ecologically and sociologically sound breeding goals is emphasized, because animal breeding determined only by short-term market forces has led to unwanted side effects. Hence, a procedure for defining animal breeding goals with ethical priorities and weighing of market and non-market values is suggested. Implementation of non-market as well as market economic trait values in the aggregate genotype as suggested may allow for breeding programs that contribute to sustainable production systems. Methods for estimating non-market values are considered. These methods include among others: contingent valuation, choice experiments, revealed preference methods, implicit pricing and expert assessments.

1. Introduction

The objective of this paper is to consider trait values in animal breeding goals for sustainable production systems. Olesen *et al.* (1999) discussed definition of animal breeding goals for sustainable production systems. They concluded that important aspects of the term sustainability are that environmental, genetic diversity, ethical and social aspects should be accounted for in addition to short and long-term economic value. The need for long-term biologically, ecologically and sociologically sound breeding goals was emphasised, because animal breeding determined only by short-term market forces has led to unwanted side effects.

Up to now, weighing of traits has mainly been based on (relatively short-term) market economic values and discounted cumulative frequency of expression. Methodology to weigh the

traits with respect to resource efficiency and economy is well developed and implemented. However, it can be questioned whether this is adequate and makes us able to incorporate the ecological, social, and ethical values properly. Proper incorporation depends to a high degree on the ability to value social, ecological and ethical aspects in monetary terms, which is a very big challenge. Weighing between different conflicting concerns and interests has to be made. Here, benefits from improved resource efficiency as well as risks of foreseen and unforeseen negative consequences should be taken into account. Some negative consequences may be taken into account via genetic correlations, other may not and should be accounted for in the breeding objective.

Here, we suggest a procedure for defining animal breeding goals with ethical priorities and weighing of market

and non-market values. Methods for estimating non-market values are considered.

2. Definition of breeding goals for sustainable production systems

Thompson and Nardone (1999) considered two different methodological approaches to sustainable livestock production: resource sufficiency and functional integrity. Contrary to the resource sufficiency approach, assumptions about both ecological and social elements and limits are made by the functional integrity approach. The threat to livestock systems can be understood in terms of increasing fragility of system interactions, and not only scarcity of natural or environmental resources. Thompson and Nardone (1999) showed how the resource availability framework of mainstream animal science already presupposes functionally integrated subsystems for regenerating key inputs. In other words, resource sufficiency includes judgements that support a conception of functional integrity, but the rhetoric used allows these judgements to remain implicit. Hence, assumptions about ethical and environmental aspects have been taken implicit. Castle (1996) argued that this often favours the status quo, even if quality of life is deteriorating due to environmental conditions. Analysing livestock production systems in light of functional integrity makes at least some assumptions on (relative) importance of aspects (e.g. productivity versus animal welfare) in human-ecosystem interactions explicit. This enhances discussion on these assumptions, and facilitates evaluation and agreement on

these very fundamental issues. These issues of (relative) importance of productivity, resource efficiency, animal welfare, etc. are to be made clear before we can define and agree upon animal breeding goals for sustainable production systems. This also implies that we recognise the complexity of the production and adopt a more communal people centred worldview informed by a subjective epistemology and a holistic ontology (Sriskandarajah and Bawden, 1994).

It should be noted that the livestock production system is to be optimised according to the ethical priorities and that the objective of animal breeding is to fit animals' traits in this system. Some may argue that such ethical priorities and valuation of, e.g., ecosystems is either impossible or unwise, because we cannot value such «intangibles» as human life, animal welfare or long-term ecological benefits. But in fact we do so every day. When we set standards for highways, bridges and the like, we value human life (acknowledged or not), because spending more money on construction would save lives. Other may argue that we should protect the environment and animal welfare for purely moral reasons, and that we therefore do not need valuations of it. Costanza *et al.* (1997) valued the world's ecosystem services and natural capital. They argued that moral and economic arguments are not mutually exclusive in such valuations, and that both discussions can and should go on in parallel.

Natural resources are valuable assets as they yield flows of services to people (Freeman, 1973). Freeman (1993) gives a comprehensive overview of valuation of natural resources and the environment. Because of externalities and the common property and public

good characteristics of at least some of these services, he states that market forces can not be relied on, neither to guide them to their most highly valued uses, nor to reveal prices that reflect their true social values. Due to this failure of the market system to allocate and price resource and environmental services correctly, there is a need for other economic measures to guide policy-making.

In order to achieve a functional integrity approach in animal breeding, Olesen *et al.* (1999) suggested a procedure where:

- The ethical aspects and priorities should be made clear.
- The system should be defined with respect to limits and structure, resource efficiency, environmental, economical and social effects.
- Indicators should be defined that measure or characterise the above ethical priorities and critical effects of the production system.
- Performance traits and characters that are important or critical to meet these criteria or objectives should be identified and balanced or weighed.

The basis for deriving measures of the economic value of changes in resource-environmental systems is their effects on human welfare. Changes in quality and quantity of animal traits have value insofar as they either change the benefits associated with human activities or change the costs of those activities. These changes in benefits and costs either have an impact on human welfare through established markets or through non-market activities. This implies that traits affecting product value (i.e., product quality) resulting from product price relationships originating from the market's supply and demand changes

should be taken into account. However, we should in addition include important non-market values of animal traits, e.g., ethical values of improved animal welfare through less suffering from diseases or stress and a higher quality of life. There may also be other values of natural capital and ecosystem services improved by changes in traits. Improvement of traits may contribute to, e.g., slower depletion of fossil energy and reduced degradation of the atmosphere. These values are not easily traceable through well functioning markets. Such values accrue directly to humans without passing through the money economy at all. Hence, the traits' values in the aggregate genotype may be split in non-market values (NV) and market values in the money economy (ME) as suggested by Olesen *et al.* (1999). Correspondingly, we will obtain a genetic gain of non-market value in addition to a market genetic gain. This gives the following breeding goal (considering true breeding values for two traits, G_1 and G_2):

$$H = [NV_1 \times G_1 + ME_1 \times G_1] + [NV_2 \times G_2 + ME_2 \times G_2] .$$

Non-market trait values are to be defined and combined with «traditional» economic values. For example, reduced disease frequency increases both the ethical values through improved animal welfare and through reduced economic costs of treatments and reduced yield. A trait may as well have only non-market value or only market economic value. The value of the non-market gain is $NV_1 \times \Delta G_1 + NV_2 \times \Delta G_2$, where ΔG_i is the genetic change in trait i , and likewise for the market gain. The total genetic gain is a sum of the non-market genetic gain and market genetic gain. The resulting

non-market and market genetic gains give us an opportunity to evaluate the breeding programs in a more holistic perspective, where both social, cultural (including subjective values), ecological, and economic objectives and effects can be taken into account.

3. Methods for estimating non-market values

There is now a vast literature on valuation of natural resources and the environment. Braden and Kolstad (1991), Freeman (1993) and Smith (1993) gave excellent literature surveys on methods for obtaining empirical estimates of environmental values. A total economic value includes both the use (consuming or non-consuming) and non-use value. Non-use values include passive use, option- («insurance premium»), existence-, intrinsic- or bequest value. The valuation methods can be used to estimate marginal changes in quantity or quality of the total

economic value of natural resources. Different methods measure different components of the total value. Other non-market values, e.g. ethical value of animal welfare, can also be estimated by some of these methods. For example, contingent valuation (CV) has been applied to value people's willingness to pay for animal welfare (Bennett, 1996). The author concluded that the methodology could provide very useful information to policy makers and others interested in public perceptions and concerns about animal welfare and public support for animal welfare policies. Valuation methods based on individual preferences are mostly considered as «environmental valuation techniques». They are usually divided into stated and revealed preferences, and further into direct methods and indirect methods. Here, we will concentrate on these methods that may be most useful in animal breeding. However, a more complete overview of valuation methods include:

I Methods based on individual preferences

- 1) Stated Preference methods
 - Direct - Contingent Valuation (CV) method
 - Indirect - Choice Experiments
(Conjoint Analysis, Contingent Ranking, Pairwise Comparison)
- 2) Revealed Preference methods
 - Direct - Simulated Markets (Real payments)
 - Indirect - Travel Cost Method (TCM)
 - Hedonic Price Method (HPM)
 - Preventive Expenditures

II Methods based on the Opportunity Costs Principle

- Restoration Costs

III Methods based on decision-makers and politicians revealed preferences

- Implicit Pricing

IV Methods based on experts preferences

- Expert Assessments - Delphi techniques
 - Multi-attribute Decision Analysis
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3.1. Methods based on individual preferences

3.1.1. Contingent valuation

Contingent valuation is the most popular valuation method, because it can measure all parts of the total economic value, and may measure future and/or hypothetical changes. The National Oceanic and Atmospheric Administration (NOAA) convened a panel of distinguished economists to conduct hearings on the validity of the CV method. The NOAA panel concluded, that CV studies produce reliable starting points for a judicial or administrative determination of natural damages, including passive use values (i.e. non-use values or existence and preservation values), when they adhere closely to the detailed guidelines specified by the panel (Arrow *et al.*, 1993). Comprehensive accounts of the method can be found in Mitchell and Carson (1989), Hanley and Spash (1993) and Bateman and Willis (1995). The study is based on surveying of people's willingness to pay (WTP) for a certain improvement of a service, e.g. animal welfare, or willingness to accept compensation (WTAC) for a certain reduction in e.g. animal welfare. The study consists of five stages:

The hypothetical market. Setting up a hypothetical market, where a reason for payment for the service (e.g. animal welfare) is given. How the improvement will be financed needs to be described (e.g. through taxes, subsidies, increased prices). It is important to clarify whether all consumers will pay for the change or improvement and to provide sufficient information about the good being valued.

Obtaining bids. Face-to-face interviewing, telephone interviewing or

mail can do this. People are asked to state their maximum WTP or minimum (WTAC) for the increase or decrease in the subject of the survey. For example, WTP may be derived in several ways:

- as a bidding game,
- as a payment card with a range of values, income and expenditure on other publicly provided services,
- as an open-ended question without suggested values,
- as a closed ended referendum, where a single payment is suggested, to which the respondents either agree or disagree.

In-person interviews with such dichotomous choices (DC) have many advantages and have been recommended by the NOAA panel (Arrow *et al.*, 1993).

Estimate average WTP /WTAC. The calculation is straightforward for open-ended, bidding game or payment card approaches. If a DC method has been used, the random utility theory (Haneman, 1984) is applied. An alternative approach to calculate welfare measures from DC data is given by Cameron (1988).

Estimate bid curves. Investigating effects on WTP/WTAC is useful in aggregating results (stage 5) and for validating the CV study. For open-ended CV formats (methods 1, 2 and 3 above), WTP bids might be regressed against income, education and age as well as a variable measuring the «quantity» of the subject valued.

Aggregate data. The mean bids are converted to a population total value figure, which should include all those components of value found to be relevant (existence value and use value). By inserting population values for the relevant variables in the bid curve we can derive an estimated population bid.

Multiplying with number of households we can obtain an estimate of the total population value. Furthermore, if the present value of environmental benefit flowing over time is of interest, benefits are normally discounted.

Because of the hypothetical nature of CV, several potential biases may occur. The major types of biases are:

- Strategic bias (respondents behave strategically by acting as «free riders»),
- Information bias (lack of information given to the consumer in the contingent market),
- Hypothetical bias (will the people behave similarly in an actual real market?),
- Constant budget bias (respondents' mental budgets for e.g. environmental goods),
- Embedding (value of the good depends on the extent to which it is embedded in other goods),
- Sampling, interviewer or non-respondent bias.

In addition, disparities have been observed in empirical studies between WTP and WTAC. For a thorough discussion of the advantages and disadvantages of the CV method, see Mitchell and Carson (1989). Although the CV is an acknowledged method for measuring non-market values, there seems to be a consensus that there is space for further development of the method. Empirical studies using the method should therefore be combined with methodological tests. Bennett and Larson (1996) explored the application of CV to animal welfare issues. Their findings suggest that CV may be applied to such animal welfare issues. However, such studies need to formally address the problems of embedding, purchase of moral satisfaction and failure of

respondents to adequately consider substitute and complementary goods, and their potential effect of overstating WTP.

3.1.2. Choice experiments

In choice experiments, respondents are asked to choose between different products with different attributes and prices. For example, the products may result from different breeding programs with different breeding objectives. The respondents may be asked to choose between pairs of products or to rank several products with respect to their preferences.

3.1.3. Simulated markets

Because CV methods consider hypothetical and non-observed behaviour, we may ask whether people actually will pay what they have said they are willing to. For example, experimental auction markets can be constructed where a group of persons may get a total amount of a product or service or a specific budget. They can spend this to buy a smaller or bigger amount of the product or service to be valued with another (improved or decreased) quality in order to improve their own welfare. The resulting prices the experimental consumers pay reflect their maximum WTP for a specific quality improvement. Studies investigating if people actually will pay what they have answered in CV-studies have been carried out and suggest that hypothetical bids tend to overstate «real» values obtained in the market (Seip and Strand, 1990; Duffield and Patterson, 1991; Navrud, 1991). However, results from CV studies can be calibrated to actual market data. Shogren (1993) introduced the idea of CVM-X, which combines the advantages of the CV

method and experimental auction markets. Hence, the validity and accuracy of surveys can be obtained while broadening the scope of non-market valuation in the lab. First, a CV survey is carried out, and secondly sub-samples of the CV respondents are brought into the lab to give bids for the actual good in an incentive-compatible auction with real goods, real money and repeated market experience. A calibration function relating the auction market bids to the hypothetical bids can then be estimated and used to adjust the values of CV respondents who did not participate in the laboratory auction.

3.1.4. Indirect methods of revealed preferences

The travel cost method is the oldest non-market valuation techniques, and is widely used in outdoor recreation modelling. It is based on the market for transport services to a limited recreation area. A demand curve for the area's recreation services is estimated. Under a set of assumptions, the recreation value of the area is further measured as the sum of the visitors' consumption surplus at their travels to the area. This method is based on actual behaviour, but can only measure the use value and underestimates the total value. Fletcher *et al.* (1990) give a survey on this method.

The hedonic price method is also based on actual behaviour, and is used for studying market prices of properties and houses in areas with different environmental quality (particularly air quality, noise and smell). Hence, people's willingness to pay for living in areas with better environmental quality can be estimated. Assumptions about indicators for environmental quality, for which people can observe marginal

changes, are needed. Furthermore, other aspects contributing to the properties' values should be identified and accounted for.

The costs of activities that reduce the risk of death or diseases, e.g. installation of smoke detectors, use of safety belts and air cleaners, have been used to value risks of human diseases and death. This is referred to as preventive expenditures. The human capital method has been used to study differences in salaries for occupations and jobs with different risks of death and accidents (i.e. workers' compensation demand). However, it is a controversial method for valuing human lives.

3.2. Desired gain approach

Construction of selection indices to change a trait at a certain rate relative to the rates of change in other traits has been used in animal breeding for quite a while. This can be a specification of the relative rates of genetic change in all traits in the aggregate genotype (Pesek and Baker, 1969; Yamada *et al.*, 1974) or a specification of the relative changes in some traits combined with a maximum aggregate change in the remaining traits (Tallis, 1962).

Selection indices with such and other constraints are reviewed by Brascamp (1984). A simple introduction to desired gains selection objective can be found in Cameron (1997).

When relative changes are predetermined for all traits, the inferred total economic values of the traits, which correspond to the desired responses in the case of an unconstrained selection objective can be obtained as follows:

$$a_D = (G'P^{-1}G)^{-1}d$$

where G = the genetic covariance matrix between traits in the selection objective

and the traits in the selection criterion (index), P = the phenotypic variance-covariance matrix of traits in the selection criterion, d = the vector of relative genetic changes. Non-market values can then be derived as the differences between the total economic values in a_D and the market economic values derived by traditional methods. These can be used further to study the non-market genetic changes that can be expected from selection on the index.

5. General discussion and conclusions

Olesen *et al.* (1999) reviewed definitions of sustainable agriculture and aquaculture. From the definitions of sustainability reviewed, they concluded that the unilateral market economy is not sufficient for determining the direction of agricultural and aquacultural development. During the last century, it has had considerable impact on the development of agriculture, and it has shown to be unable to take properly into account resource efficiency, environment and social aspects (Daly, 1993). Hence, short-term profit is incompatible with the long-term objective needed for sustainable agriculture and aquaculture as defined here. Costanza *et al.* (1997) also emphasised that we must begin to give the natural capital stock (in contrast to human made capital) that produces ecosystem services adequate weight in the decision making process. Otherwise, current and continued future human welfare may suffer drastically. Because ecosystem services are largely outside the market and uncertain, they are too often ignored or undervalued, leading to the error of designing breeding schemes

whose social or ecological costs may outweigh their benefits.

Methods for estimating non-market values have already been developed and can be applied for animal breeding purposes. However, further development and adjustment of these methods to animal breeding is needed, as little experiences have been made and have been documented on this so far. Application of the suggested procedure for defining breeding goals, that require ethical priorities and include non-market values in the aggregate genotype, may allow for breeding programs that contribute to sustainable production systems.

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