

Quality of life means welfare: how is it related to other concepts and assessed?

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Abstract

Our view of which individuals should be the subjects of our moral actions is expanding to include more people and more species. Animal welfare is the subject of rapidly increasing concern in most countries in the world, and this concern is resulting in changes in the ways in which animal users keep and treat animals. Ethical decisions about whether the killing of an animal is justifiable should be considered separately from those about how poor welfare can be and still be acceptable. The term 'euthanasia' should be restricted to killing an animal for its own benefit. Quality of life (QoL) in humans is generally taken to include: physical condition and any impairment of this resulting from injury or disease; capacity to function; perception of functioning; and satisfaction with functioning in relation to what is believed possible. If the welfare of an individual is its state as regards its attempts to cope with its environment, then welfare is essentially the same as QoL. Both include the state of the individual's coping systems, including those responding to pathology, various behavioural and physiological responses, and cognitive processes associated with suffering or pleasure. Hence, both welfare and QoL include health and the extent of positive and negative feelings. Many papers referring to animal welfare include objective quantification whilst few papers referring to QoL do so. Some human studies assess QoL by the less objective method of questions asked of subjects. Neither QoL nor welfare should be assessed using solely subjective measures. Assessment of welfare must take account of the wide variety of coping systems and coping strategies used. A range of measures including those of behaviour, physiology, brain function, immune system function, and damage is needed. The ease or difficulty of coping should be interpreted within the framework of the abilities of the animal. Animals with more sophisticated cognitive functioning may have the best abilities to cope with problems. The scheme presented here for assessing welfare over time facilitates ethical decisions regarding whether welfare is good or whether it is unacceptably poor.

Keywords: animal welfare, euthanasia, feelings, health, quality of life, stress

Are we concerned about the welfare of non-human animals?

Morality has a biological basis and has evolved (Broom 2003, 2006c). Moral actions are directed towards those considered to be 'us', but the concept of 'us' has extended over time for humans, perhaps in this order: those recognised as close relatives, those who know who I am or could do so, those who might have access to the same information as I have, and those who share characteristics with me. Hence, with improved communication we have included more people, and with improved knowledge we have included more animals. I consider that we have moral obligations towards all humans and other animals with which we interact. If we use an animal, we take on an obligation towards it. Each of us should think about our obligations. As people sometimes claim unreasonable rights and focus on what they should receive rather than on what they should give when referring to rights (Broom 2003), it is better to think in terms of obligations rather than in terms of rights. One of our obligations is to prevent poor welfare in animals. This view is held by many in the European Union, as Members of the European Parliament receive more letters

on animal welfare than on any other subject, and it is reflected in current EU legislation. Multinational food companies are establishing animal welfare standards because of consumer demand in many countries, and world standards are being set by the OIE (World Organisation for Animal Health) (Broom 1999b, 2001b, 2002).

Another, separate ethical decision concerns the circumstances in which an individual should or might be killed. The ethical question of whether or not an animal should be killed for human food, medical research, or entertainment can be considered independently of its welfare. The idea that we have an obligation to prevent poor welfare in animals that we use is also an ethical idea. If we are to prevent poor welfare, we should be able to assess the welfare of the animals. We also need to assess welfare when deciding whether or not the welfare of an individual is so poor that it would be right to terminate its life. Is the elderly pet or person so severely affected by disease or injury, and so unlikely to recover, that death would be better than life? The welfare of the individual is a key issue in such decisions. The word 'euthanasia' was first used to refer to such a situation. The origin of the word is 'good death' with

the implication that all aspects are good. Euthanasia is the killing of an individual for its own benefit. The word is often misused by those who wish to kill the animal for their own benefit. We have another term, 'humane killing', for situations such as the killing of animals for human food, or in laboratories, or because they are unwanted pets. 'Euthanasia' should not be the term used in any of these circumstances unless it is a good death in the sense that it is for the benefit of that individual animal.

What is meant by 'quality of life'?

Who uses the term 'quality of life' (QoL)? It is principally used when referring to people who are ill or recovering from illness. The related term 'quality of living' is also used in relation to the services and facilities available to people in cities. More recently, there has also been reference to QoL of companion animals, for example when they are ill, after operations such as castration, or when euthanasia is being considered.

In judging QoL to be poor, account would usually be taken of factors such as disease with substantial and prolonged effects, frequent emergency physiological responses, abnormalities of behaviour, and situations likely to lead to bad feelings such as pain. QoL would not normally be judged to be good unless negative effects such as pathology or harmful behaviour were absent and there was more pleasure than suffering. In order for QoL to be good, the individual has to be able to control its interactions with its surroundings.

Whenever the term QoL is used about an individual, there is an assumption that a negative effect, such as pain or lack of control, or a positive effect, such as a balance of pleasure over suffering, continues for some time. We do not talk about poor QoL when the experience is of pain or fear for just a few minutes; neither do we refer to better QoL because of a moment of pleasure. It is possible for a brief experience to affect QoL, but this is due to recurring effects or memories of that experience.

Some of the abilities involved in the control of the effects of the environment on the individual are simple responses. For example, when ambient temperature increases, body temperature might be adequately regulated by sweating. However, other methods of control require evaluation and prediction and hence high-level brain function. For example, the method for preventing excessively high body temperature could necessitate remembering where there is a shaded place, evaluating whether or not a predator or competitor is likely to be present at this time, and then navigating to that place. Both positive and negative feelings also involve some high-level brain function (Broom 1998).

How does this concept of QoL relate to the widely used scientific concept of welfare? This issue, and relationships to other linked concepts, will now be considered.

What is meant by 'welfare'?

Welfare is a term which is restricted to animals, including man. If, at some particular time, an individual has no problems to deal with, that individual is likely to be in a good state that would be associated with good feelings and

indicated by body physiology, brain state and behaviour. Another individual may face problems in life that are such that coping is not possible. Coping implies having control of mental and bodily stability, and prolonged failure to cope results in failure to grow, failure to reproduce or death. A third individual might face problems but, using its array of coping mechanisms, be able to cope, although only with difficulty. The second and third individuals are likely to show some direct signs of their potential failure to cope or difficulty in coping and they are also likely to have had bad feelings associated with their situations. The welfare of an individual is its state as regards its attempts to cope with its environment (Broom 1986). Hence welfare is a characteristic of an individual at a particular moment or for a longer period of days up to years. The origin of the concept is how well the individual is faring or travelling through life (Broom 1991a,b, 1998, 2006b; Broom & Johnson 2000).

The term 'environment' in the definition of welfare means, for an individual, something that could have an effect from outside that individual, or, for any particular response system, something that could have an effect from outside that system. Potentially damaging challenges may come from outside the body, eg pathogens, causes of tissue damage, or attack by conspecifics, or from within it, eg anxiety, boredom or frustration, perhaps because of lack of key stimuli or lack of overall stimulation. Other impacts of the environment may be positive and lead to better welfare. For humans and other social animals, both the challenges and the positive impacts come especially from the social environment (Mendl 2001; Broom 2003). In some cases, these impacts are associated with pleasant experiences and linked to the reward system in the brain (Spruijt *et al* 2001).

It is generally accepted by animal welfare scientists that the concept of welfare refers to the measurable state of the individual on a scale from very good to very poor. Since welfare can be poor, it is not logical to speak of preserving, ensuring, or compromising welfare.

Welfare measurements should be based on knowledge of the biology of the species and, in particular, on knowledge of the methods used by animals to try to cope with difficulties, of signs that coping attempts are failing, and of indications of success in coping. The measurement and its interpretation should be objective. Good welfare often involves good feelings and poor welfare involves bad feelings. Indeed, feelings are biological mechanisms which are an important part of coping methods. Pain, fear, achievement pleasure, sexual pleasure etc are adaptive and have evolved as a result of natural selection like other biological mechanisms (Broom 1998).

Quality of life is welfare

'Quality of life' is essentially the same in meaning as 'welfare'. However, whilst welfare can be considered over the short-term or the long-term, QoL usually refers to a characteristic of an individual over a time-scale longer than a few days. It is a state of the individual that will vary from good to bad. As explained in the later sections of this paper, welfare includes the feelings of the individual and other

factors associated with coping well, coping badly, or not coping at all with the environment. It is well established that welfare can be assessed scientifically. Proper assessment of welfare is needed whenever QoL is seriously discussed. Hence, the QoL of an individual is its state as regards its attempts to cope with its environment during a period of at least a few days. Put more briefly, the QoL of an individual is its welfare during a period of at least a few days, whereas welfare is used when referring to very brief or very long time-spans. Since 'welfare' is an established scientific term and is quantified objectively in many scientific papers, whereas QoL has been less rigorously evaluated, and QoL is just a subset of welfare, it is generally better to use the term 'welfare' rather than 'quality of life'.

Welfare and adaptation

In order to use animals in a human-orientated environment, and to ensure that the welfare of those animals is good, we need to know about the abilities of animals to adapt. At the individual level, adaptation is the use of regulatory systems, with their behavioural and physiological components, to help an individual to cope with its environmental conditions (Broom 2006a). This use of the term 'adaptation' assumes that the environment is dynamic and hence that the systems for adaptation and coping include allostatic components that prepare the individual for complex changes.

Poor welfare is often associated with an individual's lack of control over its interactions with the environment, ie with difficulty in adapting. The lives of most mammals and birds include many occasions when coping is done better if the animal uses high-level cognitive skills. Indeed, the form of poor welfare known as depression in humans and other animals occurs when such skills are not effectively used (Irwin 2001). Hence, we need to study sophisticated coping methods such as predicting, based on experience, that the pain will go away. If the animals with the highest levels of cognitive ability have the greatest potential for coping, pain may cause worse welfare for simpler animals than for complex animals (Broom 2006c).

Welfare and needs

When attempting to determine what is an appropriate environment for an animal, most scientists involved in welfare research would agree with Appleby (1997) that a range of components of that environment, each of which is to some extent variable, should be considered. The environment is appropriate if it allows the animal to satisfy its needs. Animals have a range of functional systems controlling body temperature, nutritional state, social interactions, etc (Broom 1981) which, together, allow the individual to control its interactions with its environment and hence to keep each aspect of its state within a tolerable range. The allocation of time and resources to different physiological or behavioural activities, either within a functional system or between systems, is controlled by motivational mechanisms. When an animal is actually or potentially homeostatically maladjusted, or when it must carry out an action because of some environmental situation, we say that it has a need. Hence, a

need is a requirement, that is part of the basic biology of an animal, to obtain a particular resource or respond to a particular environmental or bodily stimulus (Broom & Johnson 2000). As pointed out by Broom (1997), these include needs for particular resources and needs to carry out actions, the function of which is to obtain an objective (Toates & Jensen 1991; Broom 1996). Needs can be identified by studies of motivation and by assessing the welfare of individuals whose needs are not satisfied (Hughes & Duncan 1988a,b; Dawkins 1990; Broom & Johnson 2000). Unsatisfied needs are often, but not always, associated with bad feelings, whereas satisfied needs may be associated with good feelings. Indeed, the substantial literature on reward systems and affective neuroscience lend much support to the argument for the existence and importance of needs (Panksepp 1998; Spruijt *et al* 2001). When needs are not satisfied, welfare will be poorer than when they are satisfied.

Some needs are for particular resources, such as water or heat, but control systems have evolved in animals in such a way that the means of obtaining a particular objective have become important to the individual animal. The animal may need to perform a certain behaviour and may be seriously affected if unable to carry out the activity, even in the presence of the ultimate objective of the activity. For example, rats and ostriches will work, in the sense of carrying out actions which result in food presentation, even in the presence of food (Inglis *et al* 1997). In the same way, dogs need something to chew on, even if satiated with food, pigs need to root in soil or some similar substratum (Hutson 1989), birds need to preen and dust-bathe (Vestergaard 1980) and many birds and mammals need to build a nest before giving birth (Brantas 1980; Arey 1992). In all of these different examples, it is not logical to qualify the word 'need' by 'physiological' or 'behavioural', as every brain function is in some way physiological and much of the brain's output is behavioural. However, the need may be satisfied only when some physiological imbalance is prevented or rectified, or when some particular behaviour is shown.

Welfare and health

The word 'health', like 'welfare', can be qualified by 'good' or 'poor' and varies over a range. However, health refers to the state of body systems, including those in the brain, which combat pathogens, tissue damage or physiological disorder. Welfare is a broader term covering all aspects of coping with the environment and taking account of a wider range of feelings and other coping mechanisms than those that affect health, especially at the positive end of the scale. Health is the state of an individual as regards its attempts to cope with pathology. Hence 'health' is encompassed within the term 'welfare', and indeed is a very important part of welfare.

Although people regularly refer to poor health, they sometimes use the word health to mean absence of illness or injury in the same way that people refer to welfare when they mean good welfare. In precise scientific use, health should refer only to states varying from very good to very poor, and 'preserving health' should be 'preserving good health'.

Box 1 Measures of welfare.

Physiological indicators of pleasure
 Behavioural indicators of pleasure
 Extent to which strongly preferred behaviours can be shown
 Variety of normal behaviours shown or suppressed
 Extent to which normal physiological processes and anatomical development are possible
 Extent of behavioural aversion shown
 Physiological attempts to cope
 Immunosuppression
 Disease prevalence
 Behavioural attempts to cope
 Behaviour pathology
 Brain changes
 Body damage prevalence
 Reduced ability to grow or breed
 Reduced life expectancy

(From Broom 2000)

Health is a part of welfare and hence disease always has some adverse effect on welfare. There can also be effects of welfare in general on likelihood of disease, because specific aspects of health may be made worse when welfare in general is poor (Broom 1988; Broom & Kirkden 2004; Broom 2006b). The sequence could start with infectious disease that then causes poor welfare. Alternatively, inadequate housing conditions or transport in bad conditions could lead to poor welfare and hence to increased disease susceptibility. If animals became diseased as a consequence, this would result in worse welfare than that caused directly by the conditions.

Some general conclusions can be drawn about the inter-relationships between welfare improvement attempts and disease. Firstly, the net effect of actions that reduce disease is generally to improve welfare. Secondly, some conditions in animal housing cause poor welfare and lead to some degree of immunosuppression, thus tending to increase the amount of disease, but are at the same time effective in minimising exposure to pathogens. The balance between these effects should therefore be carefully considered in any attempts to improve welfare. Thirdly, some diseases such as those that cause lameness in cows are production-level- or system-related, whilst others such as foot-and-mouth disease are dangerous infectious diseases. Whilst we have quite a lot of information about the former, the latter should also be borne in mind when developing new systems for housing and managing animals. Our overall aim should be to improve welfare in total and we should always include consideration of the effects on individuals of any disease that they might contract (Broom 1992, 2006b).

Welfare and stress

The word ‘stress’ should be used for that part of poor welfare that involves failure to cope. If the control systems regulating body state and responding to dangers are not able to prevent displacement of state outside the tolerable range, there is an increased likelihood that the individual will be harmed and it

is valuable for this to be detected. The use of the term ‘stress’ should be restricted to the common public use of the word to refer to a deleterious effect on an individual (see Broom & Johnson 2000 for more detailed information on this subject). A definition of stress as just a stimulation or an event that elicits adrenal cortex activity is of no scientific or practical value. A precise criterion for what is adverse for an animal is difficult to find but one indicator is whether there is, or is likely to be, an effect on biological fitness. Stress is an environmental effect on an individual that over-taxes its control systems and results in adverse consequences, eventually reduced fitness (Broom 2001a; see also Broom 1983; Broom & Johnson 2000). Using this definition, the relationship between stress and welfare is very clear. Firstly, whilst welfare refers to a range in the state of the animal from very good to very poor, whenever there is stress, welfare is poor. Secondly, stress refers only to situations in which there is failure to cope, but poor welfare refers to the state of the animal both when there is failure to cope and when the individual is having difficulty in coping. It is very important that this latter kind of poor welfare, as well as the occasions when an animal is stressed, is included as part of poor welfare. For instance, if a person is severely depressed, or if an individual has a debilitating disease but makes a complete recovery with no long-term effects on fitness, then it would still be appropriate to say that the welfare of the individuals was poor at the time of the depression or disease. There is no good stress and where people have referred to some stress as being good, this is not stress but is stimulation that has some positive effects on the individual. If an experience is difficult to cope with but beneficial in the long-term, the welfare of the individual is poor at the time of coping difficulty, but no stress occurs.

Welfare and feelings

The general issue of awareness and the extent of any pleasure or suffering in non-human animals has been considered at length by Dawkins (1980), Panksepp (1998), Sommerville and Broom (1998) and Broom (2003, 2006c). The subjective feelings of an animal are an extremely important part of its welfare (Broom 1991b). Suffering, which occurs when one or more negative, unpleasant feelings continue for more than a few seconds, should be recognised and prevented wherever possible. When managing animals, we should endeavour to promote their feelings of contentment and happiness. However, although we have many measures that can inform us about injury, disease, and behavioural and physiological attempts to cope with the environment, we have fewer measures of the feelings of the animal. Information can be obtained about feelings using preference studies, and other information giving indirect information about feelings can be obtained from studies of physiological and behavioural responses of animals. A feeling is a brain construct, involving at least perceptual awareness, which is associated with a life-regulating system, is recognisable by the individual when it recurs, and may change behaviour or act as a reinforcer in learning (Broom 1998).

As discussed above, feelings are aspects of an individual’s biology that must have evolved to help in survival (Broom 1998), just as aspects of anatomy, physiology and behaviour

have evolved. They are used in order to maximise the individual's fitness, often by helping it to cope with its environment. It is also possible, as with any other aspect of the biology of an individual, that some feelings do not confer any advantage on the animal but are epiphenomena of neural activity (Broom & Johnson 2000). The coping systems used by animals operate on different time-scales. Some must operate during a few seconds in order to be effectual, others take hours or months. Optimal decision-making depends not only on an evaluation of energetic costs and benefits but also on the urgency of action — in other words, the costs associated with injury, death or failure to find a mate (Broom 1981, p 80). In the fastest-acting urgent coping responses, such as avoidance of predator attack or risk of immediate injury, fear and pain play an important role. In longer-duration coping procedures, when various risks to the fitness of the individual are involved, feelings rather than just intellectual calculations are amongst the causal factors affecting what decisions are made. In attempts to deal with very long-term problems which may harm the individual, aspects of suffering contribute significantly to how the individual tries to cope. In the organisation of behaviour so as to achieve important objectives, pleasurable feelings and the expectation that these will occur have a substantial influence. The general hypothesis advanced is that whenever a situation exists where decisions are made which have a big effect on the survival or potential reproductive output of the individual, it is likely that feelings will be involved. This argument applies to all animals with complex nervous systems, such as vertebrates and cephalopods, and not just to humans. Feelings are not just a minor influence on coping systems, they are a very important part of them.

Under circumstances in which individuals are starting to lose control and fail to cope, feelings may exist. These feelings might have a role in damage limitation, and thereby play a functional role. However they might also occur when the individual is not coping at all, in which case the feelings have no survival function. Extreme suffering or despair are probably not adaptive feelings, but an observer of the same species might benefit and a scientist might use indications of such feelings to deduce that the animal is not coping.

If the definition of welfare were limited to the feelings of the individual, as has been proposed by Duncan and Petherick (1991), it would not be possible to refer to the welfare of a person, or an individual of another species, who had no feelings because of being asleep, or anaesthetised, or drugged, or suffering from a disease that affects awareness, or of a species lacking the brain potential to have sufficient awareness for feelings. A further problem, if only feelings were considered, is that many research findings relevant to welfare, such as the presence of neuromas, extreme physiological responses or various abnormalities of behaviour, immunosuppression, disease, inability to grow and reproduce, or reduced life expectancy, would not be taken as evidence of poor welfare unless bad feelings could be demonstrated to be associated with them. Evidence about feelings must be considered, for it is important in welfare assessment, but to neglect so many other measures is

Table 1 Summary of welfare assessment procedures.

General methods	Assessment
Direct indicators of poor welfare	How poor is it?
Tests of avoidance	What is the extent to which animals have to live with avoided situations or stimuli?
Tests of positive preference	To what extent is that which is strongly preferred available?
Measures of ability to carry out normal behaviour and other biological functions	How much important normal behaviour or physiological or anatomical development cannot occur?
Other direct indicators of good welfare	How good is it?

(Modified after Broom 1999a)

illogical and harmful to the assessment of welfare and, hence, to attempts to improve welfare.

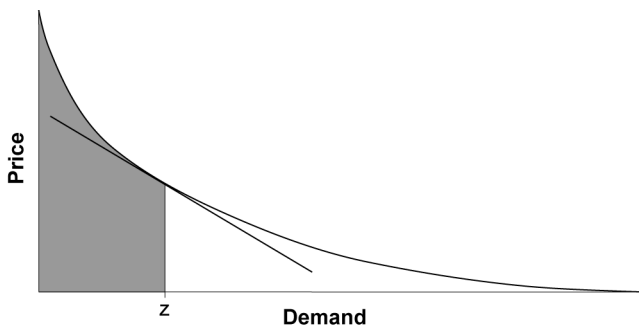
In some areas of animal welfare research it is difficult to identify the subjective experiences of an animal experimentally. For example, it would be difficult to assess the effects of different stunning procedures using preference tests. Disease effects are also difficult to assess using preference tests. There are also problems in interpreting strong preferences for harmful foods or drugs. However, research on the best housing conditions and handling procedures for animals can benefit greatly from studies of preferences which give information about the subjective experiences of animals. Both preference studies and direct monitoring of welfare have an important role in animal welfare research. Welfare assessment should involve a combination of studies that provide information about the extent to which the individual is coping with its environment.

Welfare assessment

The assessment of welfare should be quite separate from any ethical judgement but, once an assessment is completed, the information produced can be used to make decisions about the ethics of a situation. If we need to assess QoL, we should use quantitative welfare assessment methods where possible. People's assessment of welfare may vary considerably unless established methods are used. A key issue to be addressed is how good the welfare is from the animal's perspective.

The general methods for assessing welfare are summarised in Table 1 and a list of measures of welfare is presented in Box 1. Most indicators will help to pinpoint the state of the animal, ie its welfare, on a scale from very good to very poor. Some measures are most relevant to short-term problems, such as those associated with human handling or a brief period of adverse physical conditions, whereas others are more relevant to long-term problems. These measures of welfare are not 'subjective' measures; it is possible to assess QoL by the use of such measures and not just by asking the subject questions. Subjective measures in humans may be invalid or inconsistently valid. However, those who use the

Figure 1



The consumer surplus and the price elasticity of demand are illustrated on a demand curve that might be produced by evaluating the demand shown by an animal carrying out an operant response for a resource at different prices. The price elasticity of demand is given by the gradient of the curve at z , and the shaded area under the curve is the consumer surplus of the quantity z .

methodologies established for human QoL/welfare assessment and those who assess the welfare of non-human animals have much to learn from one another (see Lutgendorf 2001 and other papers in that book). For a detailed discussion of measures of welfare, see Broom and Johnson 2000.

Some signs of poor welfare arise from physiological measurements. For instance, increased heart-rate, adrenal activity, adrenal activity following adrenocorticotrophic hormone (ACTH) challenge, or reduced immunological response following a challenge can all indicate that welfare is poorer than in individuals that do not show such changes. Care must be taken when interpreting such results, as with many other measures described here. Impaired immune system function and some of the physiological changes can indicate what has been termed a 'pre-pathological state' (Moberg 1985).

Behavioural measures are also of particular value in welfare assessment. The fact that an animal avoids an object or event strongly gives information about its feelings and hence about its welfare. The stronger the avoidance, the worse the welfare whilst the object is present or the event is occurring. An individual that is completely unable to adopt a preferred lying posture despite repeated attempts will be assessed as having poorer welfare than one that can adopt the preferred posture. Other abnormal behaviours, such as stereotypies, self-mutilation, tail-biting in pigs, feather-pecking in hens, or excessively aggressive behaviour in dogs indicate that the perpetrator's welfare is poor.

With some of these physiological and behavioural measures it is clear that the individual is trying to cope with adversity and the extent of the attempts to cope can be measured. In other cases, however, some responses are solely pathological and the individual is failing to cope. In either case the measure indicates poor welfare.

Disease, injury, movement difficulties and growth abnormality all indicate poor welfare. If two housing systems are compared in a carefully controlled experiment and the incidence of any of the above is significantly increased in one of them, the welfare of the animals is worse in that

system. The welfare of any diseased animal is worse than that of an animal that is not diseased, but much remains to be discovered about the magnitude of the effects of disease on welfare. Little is known about how much suffering is associated with different diseases. A specific example of an effect on housing conditions that leads to poor welfare is the consequence of severely reduced exercise for bone strength. In studies of hens (Knowles & Broom 1990; Norgaard-Nielsen 1990), those birds that could not sufficiently exercise their wings and legs because they were housed in battery cages had considerably weaker bones than those birds housed in percheries where there was enough space to exercise. Similarly, Marchant and Broom (1996) found that sows in stalls had leg bones only 65% as strong as sows in group-housing systems. The weakness of bones means that the animals are coping less well with their environment so welfare is poorer in the confined housing. If such an animal's bones are broken there will be considerable pain and the welfare will be worse. Pain may be assessed by aversion, physiological measures, the effects of analgesics (eg Duncan *et al* 1991) or the existence of neuromas (Gentle 1986). Whatever the measurement, data collected in studies of animal welfare gives information about the position of the animal on a scale of welfare from very good to very poor.

The majority of indicators of good welfare that we can use are obtained by studies demonstrating positive preferences by animals. In operant tests, a cost is imposed upon access to the resource by requiring the subject to perform a task. Performance of the task requires time and effort, which could otherwise have been spent doing other things. The task may also be unpleasant for the subject. In choice tests, a cost is normally imposed instead upon consumption. The animal must divide time between consuming the resources.

An indicator of the effort which an individual is willing to use to obtain a resource is the weight of a door which is lifted to gain access. Manser *et al* (1996), studying floor preferences of laboratory rats, found that rats would lift a heavier door to reach a solid floor on which they could rest than to reach a grid floor. Where the demand for a resource is measured at a range of prices, the importance of the resource is indicated better by the consumer surplus than by the price elasticity of demand (Kirkden *et al* 2003); see Figure 1.

Once strongly preferred behaviours or other resources have been identified, the extent to which they can be shown (Box 1) can be assessed. It is usually clear what behaviour and other functions cannot be carried out in particular living conditions. Hens prefer to flap their wings at intervals but cannot in a battery cage; veal calves and some caged laboratory animals try hard to groom themselves thoroughly but cannot in a small crate, cage or restraining apparatus.

In all welfare assessment it is necessary to take account of individual variation in attempts to cope with adversity and in the effects of adversity on the animal. When pigs have been confined in stalls or tethers for some time, a proportion of individuals show high levels of stereotypies whilst others are very inactive and unresponsive (Broom 1987; Broom & Johnson 2000). There may also be a change with time spent in the condition in the amount and type of abnormal

behaviour shown (Cronin & Wiepkema 1984). In rats, mice and tree shrews, it is known that different physiological and behavioural responses are shown by an individual confined with an aggressor, and these responses have been categorised as active and passive coping (Koolhaas *et al* 1983; von Holst 1986; Benus 1988). Active animals fight vigorously whereas passive animals submit. A study of the strategies adopted by gilts in a competitive social situation showed that some sows were aggressive and successful, a second category of animals defended vigorously if attacked, whilst a third category of sows avoided social confrontation if possible. These categories of animals differed in their adrenal responses and reproductive success (Mendl *et al* 1992). As a result of differences in the extent of different physiological and behavioural responses to problems, it is necessary that any assessment of welfare should include a wide range of measures. Our knowledge of how the various measurements combine to indicate the severity of the problem must also be improved. It is also important to understand the strategies used by animals in various coping situations, as these may be different from those used by humans. An example is the response to severe pain in sheep and some other prey species, in which it is not adaptive to show obvious behavioural responses (Broom & Johnson 2000).

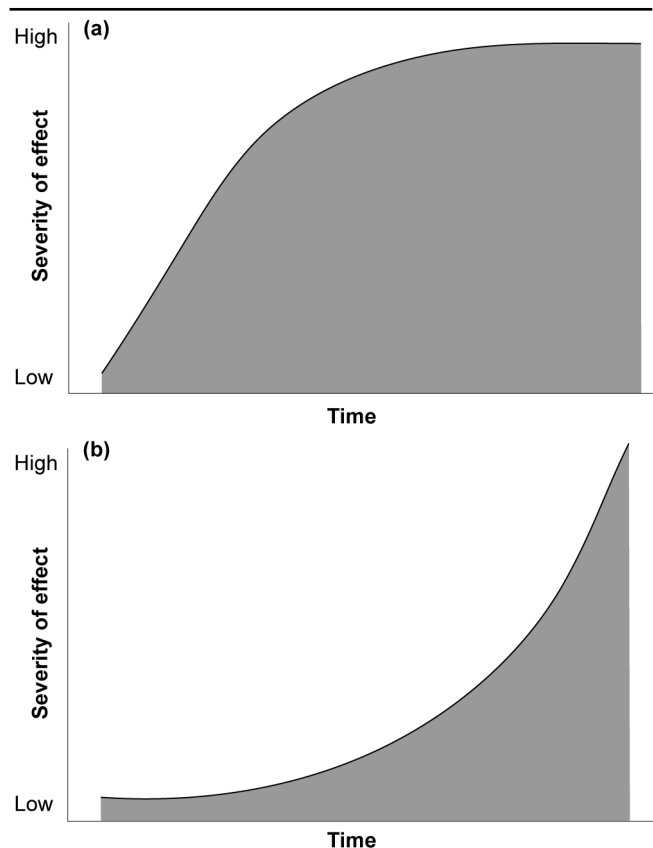
As a consequence of the high proportion of coping mechanisms that involve the functioning of higher centres in the brain, some welfare assessment should involve brain function measures (Broom & Zanella 2004). Emotional reactivity, including behavioural and brain measures of responses and of cognitive bias, can suggest long-term mental pressures, and indications of the functioning of reward systems can indicate good welfare (Irwin 2001; McEwan 2001; Spruijt *et al* 2001). Whilst welfare applies to any animal, animal protection laws generally refer to sentient animals. A sentient being is one that has some ability to evaluate the actions of others in relation to itself and third parties, to remember some of its own actions and their consequences, to assess risk, to have some feelings, and to have some degree of awareness (Broom 2006c).

In situations in which an animal has a chronic clinical condition, or a particular training procedure is used, or an animal's reaction to a kennel is to be evaluated, the welfare of that animal can be assessed using a combination of measurements. A clinician may be able to use a variety of observational methods to estimate the welfare, but accurate measurement using a suitable array of welfare indicators will give more reliable results and should be used. Where the severity of any poor welfare is assessed, the overall effect on the welfare is a function of duration and severity. In Figure 2, the area under the curve is the value required (Broom 2001a).

Conclusions

The welfare of an individual is its state as regards its attempts to cope with its environment and QoL is welfare, except that it does not refer to short time-scales. As explained above, welfare is scientifically quantifiable. QoL is a more cumbersome term and, as a consequence, it was thought necessary to abbreviate it in this volume. It is better to use the term 'welfare' in scientific publications. It may sometimes be

Figure 2



Where measures of poor welfare indicate the severity of the effect on the animal, the area under the curve when severity is plotted against duration gives a useful overall estimate of the extent of poor welfare. The maximum severity is the same in graphs (a) and (b), but the extent of poor welfare is much greater in graph (a) (after Broom 2001a).

useful to have the alternative term 'quality of life' to use in discussion with the general public. Welfare depends on extent of adaptation, a variety of coping methods, and how well needs are met. Welfare encompasses health and any stress or feelings. Feelings are biological mechanisms and are part of coping methods. Like some other coping methods, feelings involve high-level brain activity as well as simpler physiological functioning. Although many aspects of welfare involve feelings, not all of welfare is about feelings. Many feelings are not easy to evaluate and there are occasions when feelings can be misleading or absent when welfare, and hence QoL, is being assessed.

Some coping involves prediction and other complex brain abilities. Animals with more highly developed cognitive abilities probably cope better. Established methods in welfare assessment, including measures of strength of preference and scientific measures of abnormal behaviour, physiological responses and clinical condition, should be used to evaluate welfare/QoL in clinical and other situations. These can be usefully combined with accurate evaluation by observant pet-owners or veterinary surgeons. Terminology should be used precisely in this area of science, medicine and veterinary medicine.

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