

Ethics and welfare in invertebrates: A stepping-stone to research and animal production.

Augusto C. Crespi-Abril^{1,3*}, Tamara Rubilar^{2,3}

¹Instituto Patagónico del Mar, National University of Patagonia San Juan Bosco, Puerto Madryn, Argentina

²Laboratorio de Química de Organismos Marinos, Instituto Patagónico del Mar. Universidad Nacional de la Patagonia San Juan Bosco. Puerto Madryn, Argentina

³Laboratorio de Oceanografía Biológica, Centro para el Estudio de Sistemas Marinos, Puerto Madryn, Argentina

Abstract

The relationship of humans with invertebrates involves both positive and negative interaction. Even though only a few species are considered to be dangerous, pests or vectors, the majority of invertebrates produce a feeling of aversion in humans. This has contributed to the delay in the development of ethical considerations as regards this group of animals in contrast with vertebrates, with the exception of cephalopods. In the present study, we provide an overview of the current situation on animal ethics and welfare in order to contribute to the development of a framework for ensuring invertebrate welfare. Today, animal welfare is considered to comprise a scientific discipline. This is multidisciplinary in nature to a very high degree as it includes ethology, physiology, pathology, biochemistry, genetics, immunology, nutrition, cognitive-neural, veterinary medicine, and ethics. Animal welfare is a complex concept, difficult to achieve successfully from one perspective. As a consequence, we propose to include the five domains (Nutrition, Environment, Health, Behaviour and Mental State) along with the three conceptions (Basic Health and Functioning, Affective State and Natural Living), as well as the 5R Principle (Replace, Reduction, Refinement, Respect and Responsibility) in seeking to achieve a comprehensive welfare state. We consider that in both research and animal production, the individual and collective ethical concerns coexist and, in fact, the main moral concern to account for is the collective one and that, within that collective view, the individual moral concern should be applied with responsibility and respect for the individual. Finally, we propose a practical example of invertebrate welfare production in sea urchin aquaculture with the aim of including animal production of invertebrates in this important discussion.

Keywords: Invertebrate welfare, 5R principle, Animal production, Ethical concerns.

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Introduction

Humans have been using and working with animals for their own purposes throughout their entire history. The most notable uses have been, and are, for food, for transport, for research (primarily medical research), for clothes and as companions. Invertebrates are not the exception in this long history of interaction; they are fully inherent in many aspects of human lives and existence. Some aspects of these relationships are clearly positive (useful) to humans as invertebrates provide food, research models or companionship, while other aspects are negative (without purpose or, actually, harmful). This may be due to the fact that certain invertebrates are considered to be pests or vectors of human diseases. Such negative interactions with humans produce general feelings of aversion or fear towards a large number of invertebrates [1]. As a result, there are minimal ethical concerns which need to be addressed as regards these animals in order to ensure that they can be treated as a good alternative in terms of serving as models for experiments, instead of vertebrates. Currently, the most worldwide-accepted policy tool guiding practices in animal research is the Three R's principle postulated [2]. One

dimension of this principle is Replacement, which states that research should seek "any scientific method employing non-sentient material [to] replace methods which use conscious living vertebrates" [2]. Ideally, replacement should promote the use of lower levels of organization, such as cell culture and even artificial models such as computational simulations. However, in practice, the replacement dimension achieved, generally speaking, "lowers" invertebrate taxa as common models for experimental research as such taxa are considered non-sentient animals.

In recent years, the ethical concerns regarding invertebrates have started to change and several studies have established the philosophical background for incorporating invertebrates into the framework of ethics [3-6]. This change was mainly driven by the complex behavior of certain invertebrates, such as octopus (Cephalopods). The close interaction with octopus in an aquarium environment allowed for empathizing with individuals and from this relationship individuals' behaviors (personalities) could be observed and it was seen that octopus have the ability to individualize persons [5,7,8]. All of this evidence has proven that octopuses are extremely intelligent

animals and are also sentient individuals even though they do not have the same nervous system structure as vertebrates [9]. Moreover, cephalopods were included in 2013 in the EU legislation on the protection of animals used for scientific purposes at the same level of vertebrates [10]. This new insight comprised a stepping-stone in increasing the ethical concern for invertebrates as a whole [6,11,12]. A main point to emphasize is that we do not understand invertebrate behaviors, does not mean that they are not sentient or capable of reacting to negative experiences in a non-anthropocentric manner that may cause pain and suffering [13]. Simultaneous with this growing ethical concern, a significant effort has been focused on invertebrate welfare in experimental research [3,5]. However, information regarding the implications for invertebrate welfare is scattered, scant and even contradictory. Consequently, in the present study we provide a review of the current situation on animal ethics and welfare in order to contribute to the development of a framework for invertebrate welfare.

Human Perception of Invertebrates

Invertebrates represent more than 90% of the total biodiversity of the planet [1]. This vast biological sphere includes 36 invertebrates phyla of which 8 can be considered as most commonly having relationships with humans: *Porifera*, *Cnidaria*, *Platyhelminthes*, *Nematoda*, *Annelida*, *Arthropoda* (the largest phylum in animal kingdom), *Mollusca* (the second largest phylum in animal kingdom), and *Echinodermata*. Even though all of these phyla are considered to be invertebrates comprising a sole group, they could be no more diverse in nature. Their morphology, nervous systems and behavior are characteristic for each phyla and can also vary within a given phyla [11,14]. The human perception of invertebrates varies among phyla and cultures. Some are considered to comprise food (*Crustacea*, *Mollusca*, *Cnidaria*, *Echinodermata*, etc), others are used in cosmetics and pharma (*Porifera*, *Echinodermata*, *Cnidaria*, etc), others are important for culture (traditions, offerings to gods, literature, etc) and others are considered to be pests or dangerous (*Arthropoda*, *Cnidaria*, *Echinodermata*, etc). This emphasizes the point that invertebrates cannot be considered to comprise one sole group of organisms.

The human moral value of invertebrates depends on the benefit or damage a single species generates. In this manner, a species can be considered to be “good” or “bad”. However, there are many cases where one single species can be both good and bad according to human perception. For example, bees are considered a good species since they are necessary for pollination and honey production; however, bees can also be bad for allergic people and can even cause several deaths a year. Caterpillars are considered to be pests in agriculture; however, butterflies are considered to be beautiful by the majority of people. Sea urchins are considered a source of an exquisite food and are heavily fished in some regions of the world, and in other regions they are considered to be pests due to the production of barrens where kelp forests were previously growing. As a result, individual human perception may not be

the only aspect to consider in invertebrate ethics. In addition, given that each species has a particular niche necessary to preserve the ecosystem, all invertebrates species should be included in a broad ethic perspective.

Welfare: Where Science and Ethics Meet

Public concerns regarding the use of animals in experiments have been present for a long time [15]. These concerns focus on an ethical question: Do humans have the right to use animals in experiments? The answer to this question depends on the ethics framework. According to Fraser type 1 ethics would limit and create barriers for using animals [16]. In contrast, type 2 ethics allows the use of animals based on concepts of welfare [17-25]. Public concern and pressure and the type 2 ethics framework have helped to create normative, guidelines and laws to improve animal welfare during experimental research. In scientific research, the Principle of 3R helped to provide guidelines and normative practices, and the recently proposed Principle of the 5R can help to improve this normative [2,6]. In animal production, similar concerns have come to the fore and in the Brambell Report on the welfare of farm animals were issued by the British government to address these concerns and since then, such demands continue to be made [26].

Today, animal welfare is considered to comprise a scientific discipline. Animal welfare is multidisciplinary as it includes ethology, physiology, pathology, biochemistry, genetics, immunology, nutrition, cognitive-neural, veterinary, and ethics [27-33]. However, there are many different definitions of animal welfare and in literature three types of definitions of animal welfare can be found [34,35].

- Lexical definition: Definitions provided in dictionaries and generally known in society. With this definition, welfare is a wide term embracing both the physical and mental well-being of the animal [26].
- Explanatory definitions: Definitions providing the theoretical framework for lexical definitions. Here, welfare is achieved when the animal can fulfil its needs and wants with an emphasis on when the animal cannot adapt to its environment [34,36].
- Operational definitions: These are the parameters by which welfare can be measured, such as longevity, cortisol levels, normal behavior, etc.

Since the publication of the Brambell Report, animal welfare has been established as a scientific discipline evolving through different approaches [31-33,37]. There has been an evolution of concepts, from the “Five Freedoms” principle that maintains that animal welfare has to ensure compliance with the five freedoms through the improvement of conditions of animals in order to promote positive states such as satiety, vitality, reward, contentment, curiosity and playfulness to the purpose of a multifactorial and comprehensive understanding of animal welfare, by improving the “Five Freedoms” into the “Five Domains” concept in order to evaluate the impacts on animal welfare and finally, to the “Three Conceptions” that summarize

the components of animal welfare that cannot be assessed independently but, rather, need to overlap to assure welfare [37-41]. To recently incorporate the human perspective (animal taker, researcher, veterinary, etc.) with the 5R Principle based on empathy.

The “Five Freedoms” has been used as the basis in the European Union and other parts of the world to create animal protection laws. The “Five Freedoms” are: 1. Freedom from thirst, hunger, and malnutrition, 2. Freedom from discomfort, 3. Freedom from pain, injury, and disease, 4. Freedom to express normal behavior and 5. Freedom from fear and distress [38,39]. This approach has several shortcomings. For instance, only the last freedom considers the animal mental state, as the other four are based on biological needs and on preventing negative states rather than promoting positive ones. To enhance this approach, the promotion of the positive welfare states came to the fore in the improvement of animal welfare. Here, there is an active seeking to generate positive animal welfare both in research and in production [31,32,42-45].

With this new approach the “Five Freedoms” became “Five Domains”: 1. Nutrition, 2. Environment, 3 Health, 4. Behaviour and 5. Mental state. These domains integrate the biological function into the affective state. The “Three Conceptions” improved the domains, as they refer to the main important components involved in animal welfare: 1. Basic health and functioning, 2. Affective state and 3. Natural living. Each conception, by itself, cannot provide animal welfare; instead, a combination and overlapping of the three conceptions may ensure a higher level of animal welfare. Furthermore, and developed more recently, the 5R Principle comprises a more comprehensive approach including the 3R Principle but also incorporating Respect and Responsibility from the human perspective based on empathy with the aim of generating a good human-animal relationship.

Animal welfare is a complex concept, difficult to achieve successfully from only one perspective. We propose to include the 3R Principle, along with the “Five Domains”, the “Three Conceptions” within a larger framework of Respect and Responsibility (5R Principle) for animal life as shown in Figure 1.

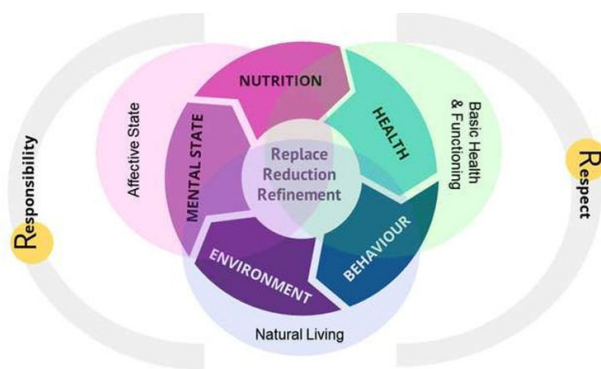


Figure 1. Animal welfare is a complex concept. It is fundamental to include multiple approaches to successfully achieve animal welfare. The overlapping of the Domains with the Conceptions including the 3R Principle within a larger

framework of the 5R Principle may help to achieve a more comprehensive animal welfare.

Assessment of Invertebrate Welfare

The assessment of animal welfare has traditionally been focused on vertebrates [46]. When the assessment is to apply to invertebrates, the task is very complex due to the level of diversity. On the first hand, the basic indicators (cortisol, longevity, feeding rate, behaviour, etc) for a welfare assessment fall into the operational definition of welfare state stated above. Secondly, the assessment only covers two of the “Three Conceptions” (Basic health and function and Natural living) and four of the “Five Domains” (Nutrition, Environment, Health and Behaviour) as in Figure 1. By definition, the basic assessment is incomplete. In addition, in invertebrates, excluding cephalopods, the Mental State Domain and the Conception of Affective State are, currently, very difficult to evaluate. Even though we do not have the tools to assess the mental states of invertebrates, there is undoubtable evidence of social behaviour in many species and it is probable that the lack of interactions with the invertebrates is a detriment in terms of their mental state [47]. Even if it is currently not possible to undertake a comprehensive invertebrate welfare assessment, it is, still, our responsibility to ensure that the highest welfare conditions possible are achieved.

It is necessary to have a set of criteria for animal welfare in order to execute an overall assessment [48]. Criteria must incorporate the following requirements:

1. Each and every important aspect must be addressed in order for the assessment to be exhaustive,
2. The criteria must not be redundant or irrelevant,
3. Each criteria must be independent of the other criteria,
4. The criteria must be agreed upon by all stakeholders and have a practical basis,
5. The criteria, as well as their application should be transparent and easy to understand and
6. The number of criteria should be limited (12 as a maximum).

Taking these recommendations into account and considering the diversity of invertebrates, it is important to acknowledge that a specific set of criteria assessing the invertebrate welfare of each Phyla, or even each Order, would need to be constructed.

Ethics in Research and In Animal Production

Individual animal ethics is based on the premise that the moral concern should be focused on the state of the individual. In other words, the moral concern should consist of thinking about the manner in which we treat the animal in terms of it experiencing its own interest [49]. This premise is based on the principle that collectives or groups of animals do not have conscious experiences [47]. Collective animal ethics considers the moral concern as regards the group, even if the interest of the collective is against, or in conflict, with the individual's interests [50].

Whilst these perspectives on ethics would appear to oppose each other, they are, actually, fully simultaneously applicable in terms of the varying situations involving human-animal relationships and, in fact, they co-exist. We consider that, first of all the main moral concern is a collective one and within the collective view the individual moral concern should be applied with responsibility and respect for the individual. For example, in research, the moral concern seems to be at individual level, since the individual response is the main goal, the requirements of statistics, such as pseudo replicas, are to be avoided and therefore individuals are kept alone in their cages or aquariums. However, under the animal welfare 5R Principle, the researcher must first apply a collective moral concern in implementing the Reduce concept (minimizing the numbers of individual harm) [2,6,47]. In animal production (e.g. farms and aquaculture), the most appropriate moral concern is a collective one without losing the individual perspective. For example, in a group with herd immunity the benefit is incurred by every individual, even those without immunization, or who are weak or ill [47]. In a similar manner, a healthy environment in farms or in aquaculture facilities benefits the collective and the individuals, considering animal welfare at both levels. Sick animals in production facilities have to be obligatorily managed, and are often removed from the group to a quarantine area or even apply euthanasia plans [51,52]. This requires both the collective and individual ethical perspectives. On one hand, the farmer takes care of the group to prevent an epidemic and in order to diminish the scope of animal harm and, on the other hand, takes care of the sick animal to recover from the disease or to minimize suffering from a slow death of that animal. We propose that with both research and animal production, the 5R Principle, in particular, the Respect and Responsibility concepts are to be applied as they involve both collective and individual ethics (Figure 2).

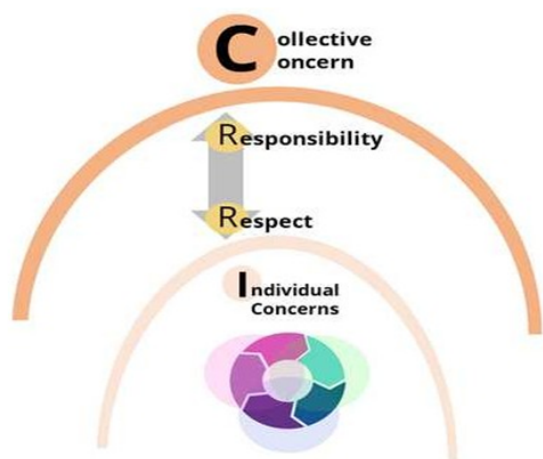


Figure 2. The main moral concern in research and production is a collective one and within the collective view the individual moral concern should be applied with Responsibility and Respect for the individual.

Practical Application of Welfare Assessment in Invertebrates: Sea Urchin Aquaculture as a Model

Sea urchins have been consumed by humans since ancient times [53]. Market demand is higher than the offer in the market and natural stocks are in decline [54]. As a result, sea urchin aquaculture is on demand [55]. In addition, global warming is compromising the fishing supply of sea urchins. October 2021 saw a massive mortality of sea urchin in Hokkaido, generating losses of more than 52 million Euros and the sea urchin natural supply of at least 5 years has been lost. In fact, there are estimates that this population will take at least 10 years to recover, making sea urchin aquaculture a priority worldwide to meet the market demand. This is a novel industry where a practical application of invertebrate welfare assessment can be undertaken from the very beginning.

There is no secret that animal production is focused on the outcome, an improved outcome and quality, and on a better profit. In animal production, as we have seen, there are laws and principles to regulate animal welfare (eg. EU 2010, Directive 2010/63/EU, 3R Principle, 5R Principle, etc) and often, better welfare will produce a better outcome and profit. However, these regulations are primarily focused on vertebrates and cephalopods. When it comes to considering low trophic species, such as sea urchins, crabs, mussels, shrimps, etc, there are, largely, no guidelines to follow. Still, the incorporation of moral concerns and invertebrate welfare will most likely improve the production and practices of aquaculture facilities. Healthy individuals are more productive and their welfare can often contribute to the overall health of the group.

As shown in Figure 1, a sea urchin aquaculture facility could be seen to require consideration of the “Five Domains” (with specific criteria), the “Three Conceptions” and the 5 R Principle, in order to secure a comprehensive welfare approach. The Domain of Nutrition refers to fulfilling the nutritional requirements of the species by offering, in this case, a specific type of sea urchin feed. This Domain can be assessed by measuring the rates of non-consumed food and feces. The Health Domain refers to the absence of disease. This Domain can be assessed on the basis of the record of the number of lost spines, the color of epidermis and immunological profiles (number and type of coelomocytes). The Environment Domain refers to the habitat. In low trophic aquaculture, the best way to achieve a good environment is through IMTA (Integrated Multi Trophic Aquaculture). This ensures good water quality, as well as a heterogeneous environment and also ensures natural refugees. This domain can be assessed on the basis of physicochemical values (temperature, salinity, ammonium, nitrite, nitrate, phosphates) in the water, as well as in terms of the microbiome present in the water. The Behaviour Domain refers to the natural behavior of the individuals. This Domain can be assessed on the basis of the “rightening behavior” (a specific behavior of sea urchins), adherence to the surface, food seeking, tube feet and spine movements, and on the aggregation of individuals. The Mental State domain in

invertebrates, especially in marine ones, such as sea urchin, is a challenging Domain in terms of determining and assessing its nature and parameters. However, knowledge regarding the behaviour of the species in nature is crucial. For example, sea urchins are often found in an aggregative distribution, i.e. patches of individuals. In animal production, the presence of this type of aggregation of individuals may most likely contribute to the mental state of the individuals. Furthermore, even if there is, at the moment, no means of assessing the impact of this distribution on the mental health of the animals, it is important to respect the natural distribution of the species. However, future evidence may provide insights into this Domain and by using the 10 criteria; it would appear to be possible to assess the welfare of sea urchins in aquaculture facilities [56-62].

Conclusion

The majority of ethical and welfare animal approaches are based on vertebrates. The work with invertebrate welfare is challenging and it will take time for both researchers and producers to embrace these concepts. However, there are major advances in this context and if there is public awareness and concern, this may help to accelerate the use of these concepts and, hopefully, one will see, quite soon, guidelines, normative and laws in this area. We have been working on invertebrate ethics and welfare for several years and we hope that animal production will also be included in this discussion regarding invertebrates.

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Declaration of Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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***Correspondence to**

Augusto C. Crespi-Abril
Laboratorio de Oceanografía Biológica
Universidad Nacional del a Patagonia San Juan
BoscoPuerto Madryn
Argentina
E-mail: crespi@cenpat-conicet.gob.ar