Chapter

The Disturbed Habitat and Its Effects on the Animal Population

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Abstract

Changes in the "habitat" may interfere with the normal functioning of all biological systems. The existence of relationships between environmental changes and health in humans and animal species is well known and it has become generally accepted that poor health affects the animal's natural behaviors and animal welfare and, consequently, food safety and animal production quality. Microclimate alterations, husbandry-management conditions, quality of human-animal interactions, feeding systems, and rearing environment represent the main factors that could negatively affect animal welfare and may produce behavioral, biochemical, endocrine, and pathological modifications in domestic and wild animals. Particularly, high stress levels can reduce the immune system response and promote infectious diseases. Adverse socio-environmental factors can represent a major stimulus to the development of different pathologies. This chapter will discuss the main pathological modifications described in domestic and wild animals due to "disturbed habitat" paying more attention to critical points detected in standard breeding systems.

Keywords: disturbed habitat, pathology, farm/zoo and wild animals, microclimate, housing systems, human-animal interactions, social interaction

1. Introduction

Disturbance has been defined as "a change in conditions which interferes with the normal functioning of a biological system" [1]. A "disturbed habitat" is an ecological concept indicating a temporary change in environmental conditions, which causes a pronounced change in the ecosystem. Disturbances can be human-caused or natural. Human disturbances include plowing, digging, construction activities, mowing, spraying weed-killing chemicals, clearing land for a garden, burning, severe livestock overgrazing, and so on. Natural disturbances include lightning strikes and fire; temperature changes, strong winds, ice storms, and tornadoes that topple or damage trees, heavy rain, flooding, hail, and erosion; and drought and earthquakes.

The existence of relationships between the changes in the environment and health is well known, and it has been documented by numerous scientific studies conducted over the past half century within all animal species and humans. Moreover, it has become generally accepted that poor health conditions can produce behavioral alterations and consequently affect the quality and safety of animal products.

In the recent years, consumers paid a great attention to the health and welfare of reared animal species. In 2007, in the article 13 of the Lisbon Treaty [2], the European Union has recognized animals as "sentient beings," capable of feeling pleasure and pain. The OIE code recognizes the "Five Freedoms" as valuable guidance in farm animal welfare/health [3]. The Five Freedoms concept analyzes the main domains related to the raising and handling of animals like feeding/nutrition, housing, health, and behavior, and it is used by various animal welfare standards to assess the animals' conditions. They were formulated in the early 1990s and are now well recognized as highly influential in the animal welfare arena. However, a marked increase in scientific understanding over the last two decades shows that the Five Freedoms do not capture, either in the specifics or the generality of their expression, the breadth and depth of current knowledge of the biological processes that are germane to understanding animal welfare and to guiding its management [4].

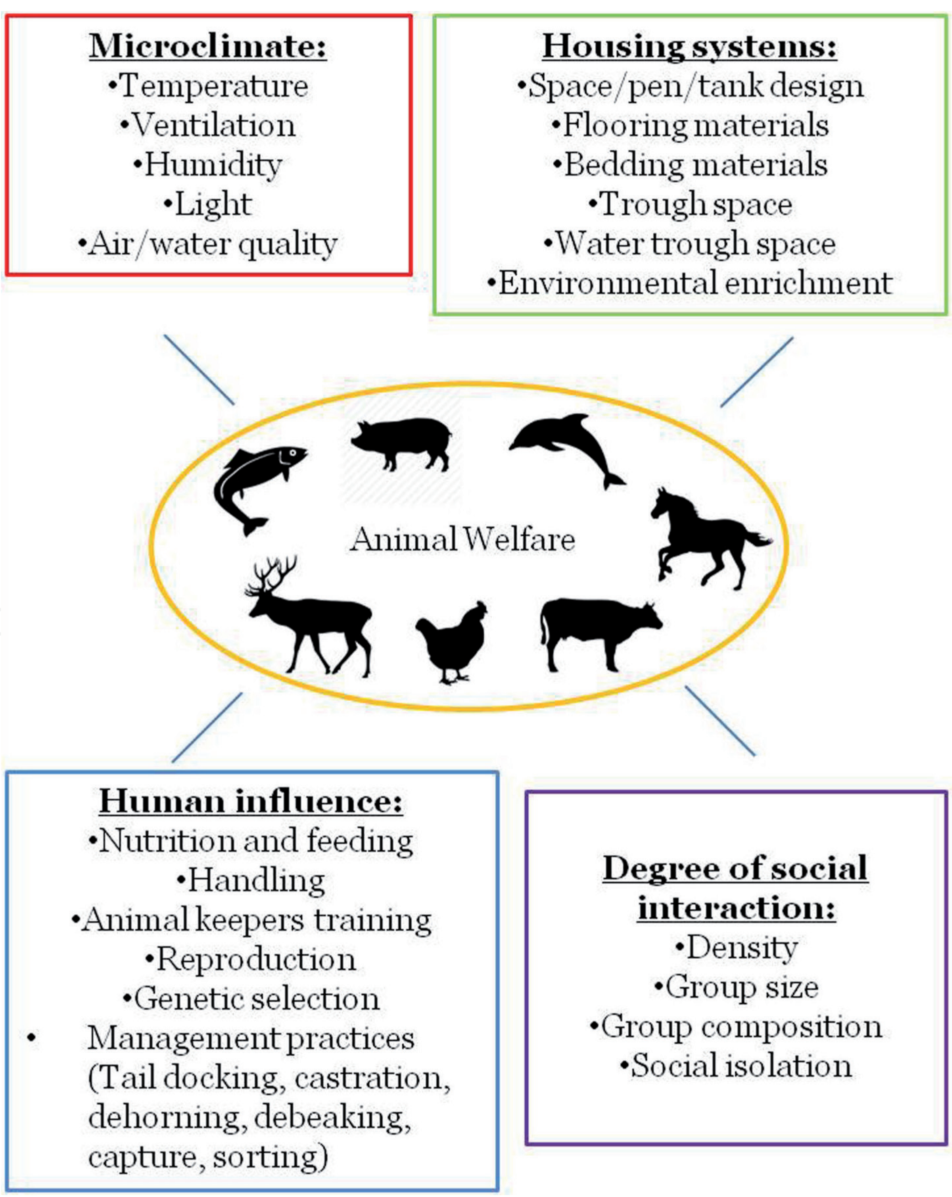

Figure 1.
Main critical points for animal welfare.

In fact, welfare criteria and parameters vary among and within species and depend directly on human utilitarian interests about them. The establishment and governance of animal care procedures impact directly on welfare of every managed species and should be carried out with "human care," thus anticipating and precisely estimating the resources to be provided to the animals by humans.

Advocacy groups often claim that animals in human care "only" deserve a good life "worth living." For animals to have "lives worth living," it is necessary, overall, to minimize their negative experiences and at the same time to provide them with opportunities to have positive experiences. To ensure this, during the last 10–20 years, national and international regulations or codes of welfare have increasingly included provisions that extend the welfare management focus to include elements well beyond the basic survival needs of farm animals [4].

Stressing factors due to an unsuitable habitat may produce behavioral, biochemical, and endocrine modifications in all the individuals that may be monitored by a series of well-known stress indicators such as the hematological profile, adrenal hormones (cortisol and its metabolites), acute-phase proteins, and d-ROMs. Biochemical modifications may lead to morphological alterations clinically manifested or not.

This chapter will discuss the pathological modifications affecting farm, zoo, and wild animals due to "disturbed habitat" addressing specific critical points (**Figure 1**) detected in standard breeding systems (**Figure 2**) for farm animals and species living in natural/semi-natural habitat for zoo/wild animals. Sections have been organized according to the following division: farm animals (cattle and small ruminants, pigs, equine species, poultry, and fish), zoo, and wild species.

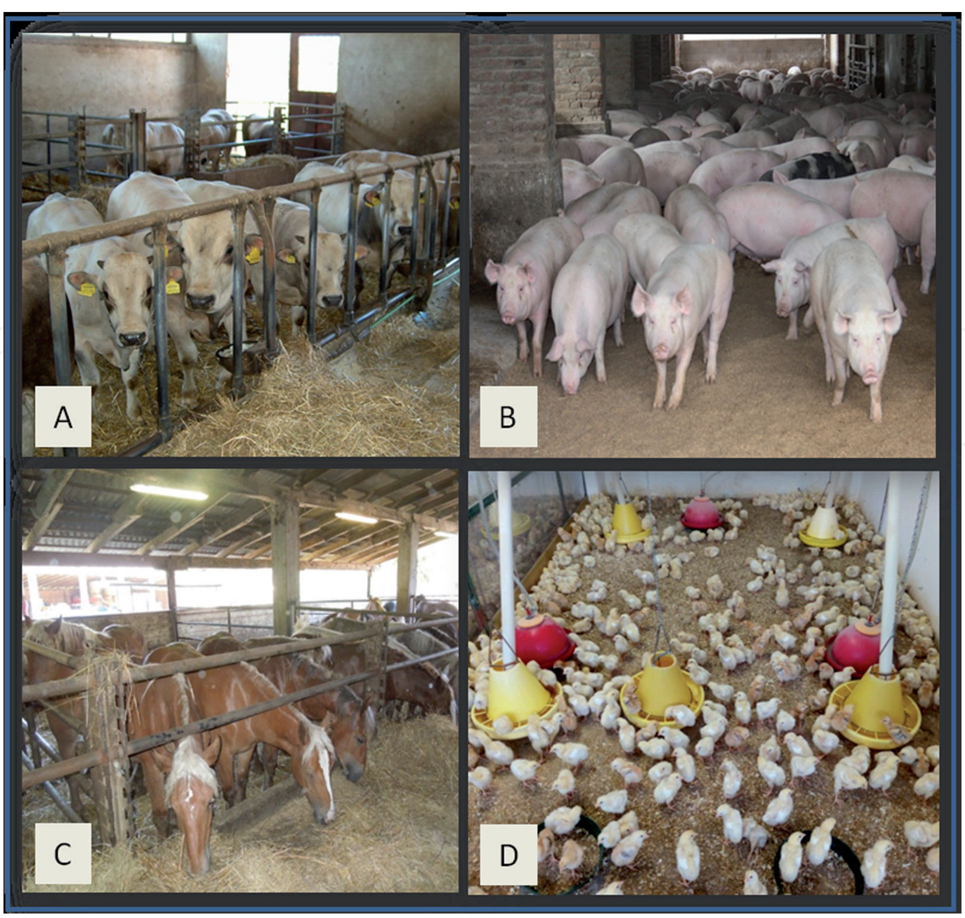

Figure 2.
Intensive livestock farming: (A) cattle, (B) pig, (C) horses, and (D) poultry.

2. Farm animals

2.1 Cattle and small ruminants

Ruminants belong to the order Cetartiodactyla, which encompasses numerous species, and only a minority has been domesticated including cattle, sheep, and goats. Although these are suited to different habitats, in intensive farming systems, domestication has led to exposure to different stressors potentially responsible of pathologies.

For centuries, cattle have been grown in a traditional manner, within small farms, mainly grazing. Since the second half of the nineteenth century, the continuous demand of protein products and the availability of grains and protein sources to low costs led to an intensive, highly specialized production system, where animals are "adapted" to meet the constraints caused by their housing conditions and the management practices [5], thus restricting their natural behaviors. Furthermore, individual selection for enhanced production traits has placed an even greater metabolic demand on these animals.

The microenvironment experienced by cattle in houses, on open feedlots or at pasture is determined by the *microclimate*. Beef cattle can tolerate and adapt to a wide range of air temperatures, and metabolic heat production increases with increasing feed intake. Microclimate changes (e.g., inadequate ventilation, extreme temperatures, high relative humidity, ammonia concentration, etc.), affect the animal's immune response resulting in **respiratory and enteric diseases**, the major welfare problems in beef cattle [6].

The *housing system* could play an important role in cattle welfare [7]. Loose housing systems allow more freedom of movement than tether systems, also offering the animals the possibility of experiencing more natural social behaviors. The resting area is one of the most important areas, especially in a cow facility. Lying down is a basic requirement, and repeated deprivation is aversive to cows. Lying times are lower and standing times are higher when dairy cattle are forced to use hard surfaces. Particularly, in dairy cow, the poor hygiene and the materials of the bedding leads to **udder problems**, as manure may compromise cow comfort and increase the risk of intramammary infections. The type of flooring on which animals walk has been found to affect their welfare by impairing locomotion and increasing the occurrence of **hoof disorders and lameness**, which represent a major concern for the dairy industry because it negatively affects milk production. Beef cattle kept on slatted floors show a higher incidence of abnormal standing and lying movements and also a higher incidence of injuries than animals kept on concrete floor with fully or partially straw-bedded areas. A long duration of grazing periods, associated with frequent manure removal during the housing period, is probably a key factor for limiting the occurrence of podal lesions.

As far as *social interactions* are concerned, mixing and regrouping of cattle increase the incidence of agonistic behaviors and have also disadvantages from a health perspective. Older and more aggressive animals may cause trauma and continuous and severe stress to lower ranking calves (bullers). Small and young animals are more prone to diseases if kept with larger and older animals. For these reasons, groups should be made up with animals of similar age, weight, and sex [5]. Moreover, overcrowding and the reduced space at the manger are one of the most critical factors negatively affecting cattle welfare by increasing competition among pen-mates, causing the buller steer syndrome, decreasing the feed intake, reducing the time spent resting, eating, and ruminating, and increasing lesions, such as trauma on bones and joints, osteoarthropathies, prepuce injury, and tail-tip necrosis. In most intensive farming systems, the separation of the dairy calves from their mother in the period immediately after birth may have negative consequences for the health and welfare of cows and calves. Particularly, the socialization of calves may profit from staying with the dam, preferentially in a group [5].

Husbandry practices can have a tremendous effect on cattle provoking an increase in the prevalence of stress responses and physical injuries [8]. In fact, a positive attitude of the stockperson in handling and taking care of the animals seems to improve cattle welfare. The age of the farmers is also responsible for the less efficient management and consequently poor welfare of the animals. Not well-trained milkers may produce **teats injuries** that predispose to mastitis.

Furthermore, the welfare of any animal clearly depends on the provision of sufficient food to supply principally energy (Net Energy [NE]), proteins, amino acids, fatty acids, minerals, and vitamins, which are essential for the functions of life (maintenance, growth, activity, and reproduction). Failure to provide sufficient NE and optimal amounts of specific nutrients can lead to severe loss of body condition, infertility, and severe metabolic disorders. Growing beef cattle, housed, yarded or on feedlots, and presented with high energy and low fiber rations *ad libitum* are at risk of **digestive disorders** (**Figure 3A**). The most common of these ones is subacute ruminal acidosis, which occurs when the fermentation rate and hence the volatile fatty acid production exceed the buffering capacity of the rumen, but it is possible to observe also fatty liver, ketosis, displaced abomasum, liver abscesses, and laminitis. Unnatural foraging regimes, possibly exacerbated by restrictive environments, are thought to elicit stereotypic oral behavior in cattle, such as tongue-rolling, object-licking, chain-chewing, or bar-biting [6].

For all the reasons stated above, the authors hypothesize that the stress related to the intensive livestock farming could also represent a mechanotransduction-promoting factor of subclinical pathological changes such as **coronary arteriosclerosis** (**Figure 3B**), which has been frequently reported at slaughterhouse in both calves and beef cattle [9].

Basically, the major farming systems of small ruminants are those based on pasture (extensive-grazing), the indoor ones (intensive-industrial), and the semi-intensive. The negative impact of intensification of breeding systems can be observed at several levels and is very similar to what has been discussed above for the cattle. However, limited studies on the small ruminant welfare have been carried out, since they are considered very rustic animals able to cope with prohibitive environmental conditions and inadequate management practices, without harming their welfare and productive performances. This aspect has been overrated for many years considering that also in sheep and goats, stress can impair growth rate, wool growth, and feed conversion efficiency, also leading to the development of multi-factorial diseases such as **mastitis, laminitis, and metabolic disorders,** and increasing the frequency of abnormal behaviors (aggressive behavior), stereotypies, and vocalizations [10].

The *microclimate* is fundamental in preventing **respiratory diseases**. Indeed, animals allocated in hot and dusty environments are more prone to develop bacterial or viral pneumonia. Additional stressors could be found in the extensive systems, such as climatic extremes, that may evoke a **decrease in feed intake efficiency** and utilization, disturbances in water, protein, energy, and mineral balances, enzymatic reactions, hormonal secretions, and blood metabolites.

The *housing system* is fundamental for small ruminant welfare too: only few animals are reared in extensive production systems in which animals are free to move and perform their physiological and behavioral functions; most of them are housed only during the night and in the periods when grazing is not feasible. In any case, it is fundamental to understand that maintenance of good hygiene conditions, correct dimensioning of structural parameters, and adoption of proper management practices are important in either type of system.

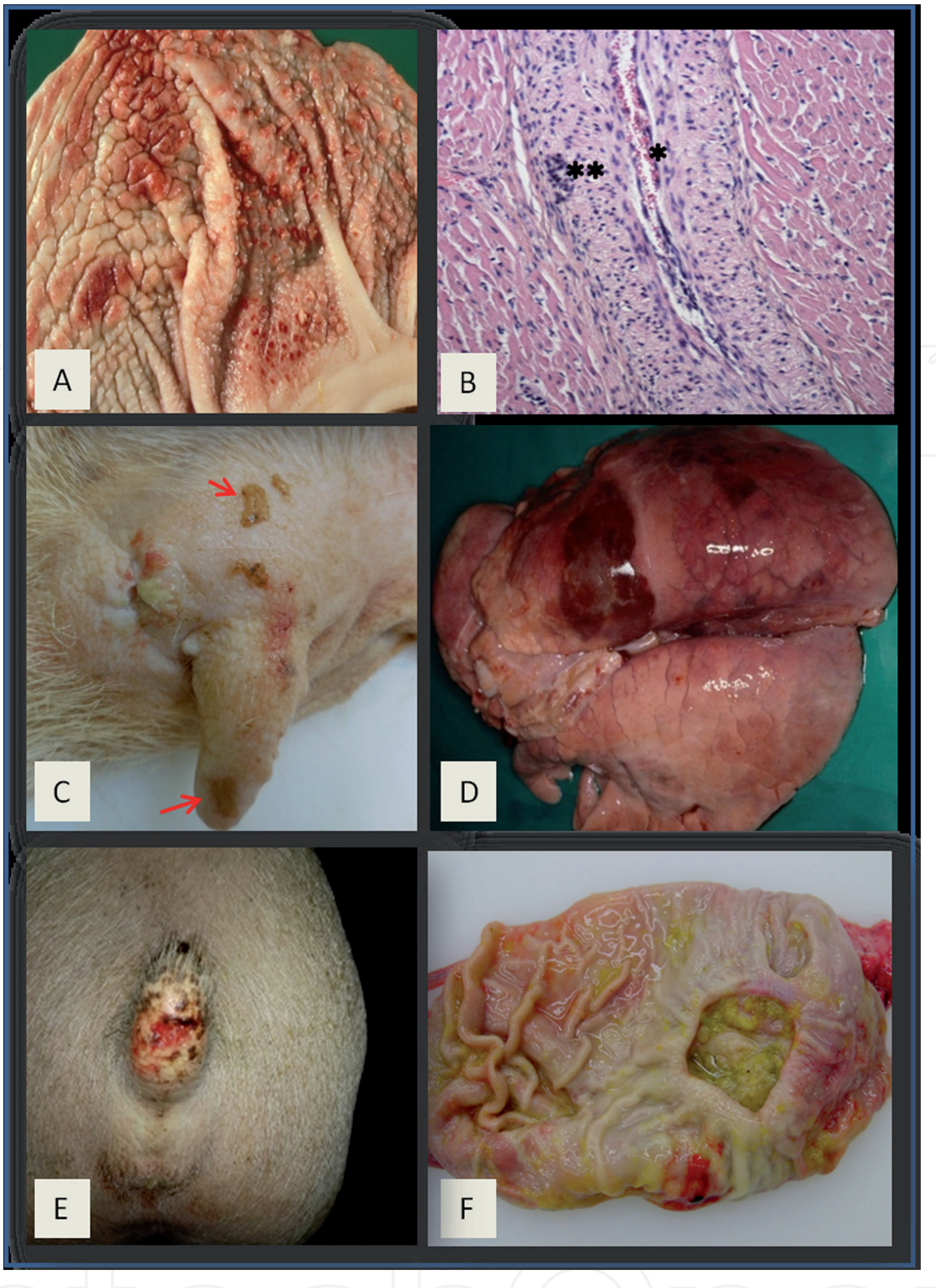

Figure 3.
(A) Beef cattle—abomasitis due to improper nutrition. (B) Beef cattle—heart. Arteriosclerotic alterations: diffuse intimal hyperplasia (*), medial smooth muscle cells reoriented and with disseminated vacuolar degeneration of the cytoplasm, moderate medial hypertrophy/hyperplasia (**). Histological section stained with H & E. Original magnification 20×. (C) Goat—udder. Traumatic teat injuries caused by milking. (D) Pig—lung. Pulmonary sequestration due to Actinobacillus pleuropneumoniae infection. (E) Pig—tail-biting lesions. (F) Pig—gastric ulcer due to improper nutrition.

With regard to *social interactions*, separation of goats/sheep from the group and re-introduction (e.g., for shearing or milking) and introduction of goats/sheep into established groups are stressful. One measure to reduce the effects of separation and re-introduction is to enable the (separated) goat/sheep to still hear and smell the other goats.

As seen above for cattle, *human-animal interaction* is a key factor also in the welfare of small ruminants too, and it is not unusual to find shepherds who have no specific skills or are not aware of the welfare standards of the animals [3]. An inadequate milking may produce teat injuries (**Figure 3C**) which is why specific training of farm crews should therefore be encouraged. Finally, an inadequate pasture in terms of quality and quantity can lead to **nutritional unbalance** with **liver disease, enzootic ataxia, pregnancy toxemia, hypocalcaemia, diarrhea,** and **enterotoxaemia.**

2.2 Pigs

Genetic selection in domestic pigs has been widely exploited in order to achieve specific phenotypic characteristics. Many pigs are raised in intensive conditions and thus strongly conditioned by the environment where they live. Moreover, even free-ranging domestic pigs and wild boars may be strongly influenced by human activities. Several signs of suffering in swine have been described and they can be quantified using animal-based measures (ABMs) [11, 12]. Furthermore, researches on pig welfare and ABMs led to the identification of "iceberg indicators" such as body injuries and ear and tail lesions. These indicators can be a proxy of "disturbed habitat" which is strongly influenced by microclimate and/or management. *Microclimate* heavily affects the stress conditions for pigs, particularly in intensive farming where different age groups require different microclimate standards (air, temperature, and humidity). If ventilation and air quality are not optimal, respiratory disorders, such as pneumonia (**Figure 3D**) and/or pleuritis from opportunistic pathogens, may occur, thus increasing the mortality. Variations in temperature and humidity (outside the thermal comfort) result in abnormal behaviors. For example, distressed pigs show increased huddling due to excessive cold weather and panting due to excessive hot weather [11]. Proper *management* is the key to maintain suitable habitat conditions for both intensive and extensive pig farming. Housing systems affect both animal behavior and physical conditions. In the intensive farming, floor types (e.g., slatted or solid), space allowance, and availability of bedding material influence incidence of bursitis, erosions, lameness, and shoulder ulcers. Moreover, the type of flooring directly affects the hygiene of the pig's body and the risk of developing enteric disorders. In the extensive farming, pigs must always have access to proper shelters; otherwise, outbreaks of severe enteric and respiratory disorders will occur increasing also the mortality rating. Appropriate structures and adequate space allowance for activities such as resting, feeding, and drinking are directly related to social behavior and interactions. Indeed, the environment in which pigs are confined influences the *degree of social interactions*. When a new group of pigs is formed, a stable social hierarchy is usually established in 1 or 2 days. During this initial phase, negative interactions arise and their outcomes may be observed mainly as wounds on the body. Once the hierarchy is established, negative interactions drastically subside while positive interactions (e.g., grooming, sniffing, nosing, and liking) and exploratory behaviors become prevalent [12, 13]. Nevertheless, rearing conditions typical of intensive housing systems can exacerbate inappropriate behaviors such as stereotypies (e.g., sham chewing) and negative interactions (e.g., ear and tail biting) (**Figure 3E**) [14]. *Human influence* on genetic selection and daily management is one of the most important variables which can exacerbate consequences of "disturbed habitat." Indeed, daily management errors, such as improper nutrition or feeding, may lead to severe conditions like gastric ulcers (**Figure 3F**) or toxic states (e.g., salt poisoning) which can cause high mortality [15]. Clear differences in the body condition scores of pigs of the same age are also a direct consequence of inadequate feeding. Genetic selection has led to great production results improving parameters such as reproductive performances, meat production, daily weight gain, and feed conversion ratio. However, this intense selection has made pigs less able to adapt to certain environmental situations (e.g., thickness of the subcutaneous fat layer), with organs at the limit of physiological potentiality (e.g., heart), leading to an increased risk of pathologies such as hernias and mulberry heart disease [16]. Pigs are also selected to be more prolific but, without adequate assistance, there is a drastic increase of newborn piglet mortality. Finally, human influence on pig management has repercussions on infectious diseases, which negatively affect pig health, such as colibacillosis, polyserositis, enzootic pneumonia, post weaning multisystemic wasting syndrome, and porcine reproductive and respiratory syndrome.

2.3 Equines for meat production

Equine meat consumption depends on cultural and traditional customs. Since it is a niche product, scientific community has made little efforts to define the main factors responsible for a "disturbed habitat" in this category. Equine breeds specifically selected for meat production do not exist and genetic selection focused more upon preserving and improving traits related to horses' morphology and performance. Therefore, although equines' domestication dates back to 5000 years ago, these species still retain the ancestral characteristics of their progenitors and feral equine populations can provide information about many aspects of equine behavior (e.g., social and foraging behavior). Considering the most important *microclimate factors* that negatively affect the equine habitat, insufficient ventilation and inadequate air quality may cause an increased exposure to gaseous ammonia and airborne dust that contain high levels of organic particulates including mite debris, microbes and vegetative material with varying content of endotoxins. The inhalant exposure to those irritant factors is implicated in the pathogenesis of **chronic inflammatory pulmonary disorders** such as inflammatory airway diseases (IAD) and recurrent airway obstruction (RAO) [17].

Equines reared for meat production are housed in conditions that markedly differ from those in which they evolved. As a consequence, those animals attempt to adapt to the conditions in which they are kept performing functionless and repetitive activity known as **stereotypic behaviors** that include crib-biting, wind sucking, box walking, and weaving [18]. Therefore, using equine stereotypies as welfare indicators should lead to perform management changes to enhance equine's welfare.

Bedding is an essential component in the *housing of the equine stabled. Bedding* should be dry, clean and not dusty, providing comfort, allowing animals to express their natural behavior of lying and resting and also avoiding the risk of **hoofs and skin lesions** [19].

Regarding the equines' opportunity to perform normal behaviors, it is important to guarantee an adequate space allowance to prevent aggressive reactions that might lead to stress competition for resources and for hierarchy establishment with consequent **physical injuries**. Indeed, wild horses live in relatively stable harem bands, so the overcrowding and the high rates of regrouping of intensively farmed horse may cause an increase in aggressiveness and injuries [20]. On the contrary, in nature, donkeys adapt easily, and their social organization depends on the availability of food and water resources. Therefore, the competition in the stabled donkeys, probably, could be increased if the available resources are not accessible to all, but their behaviors in farmed conditions need to be further studied.

Equines are grazing herbivores adapted to eating a forage-based diet. In nature, horses and donkeys spend about 16 hours per day foraging over wide distances, and this is essential for the health of their gastrointestinal tract and for their behavioral needs. On the contrary, equines in the breeding farms are fed high-energy, low-fiber concentrates, and this lack of foraging opportunity along with the high amount of concentrate feedstuff has been directly linked to the onset of **gastrointestinal disorders such as** gastric ulcerations (**Figure 4A**) and colic [19]. Equine gastric ulcer syndrome (EGUS) is reported in domesticated horses mainly involved in athletic endeavors. EGUS prevalence and severity have been correlated with the type of training and management practice. Common known risk factors have been identified in intense exercise, high grain-low roughage diet, water deprivation, fasting, hospitalization, and overdose of NSAIDs. In particular, excessive ingestion

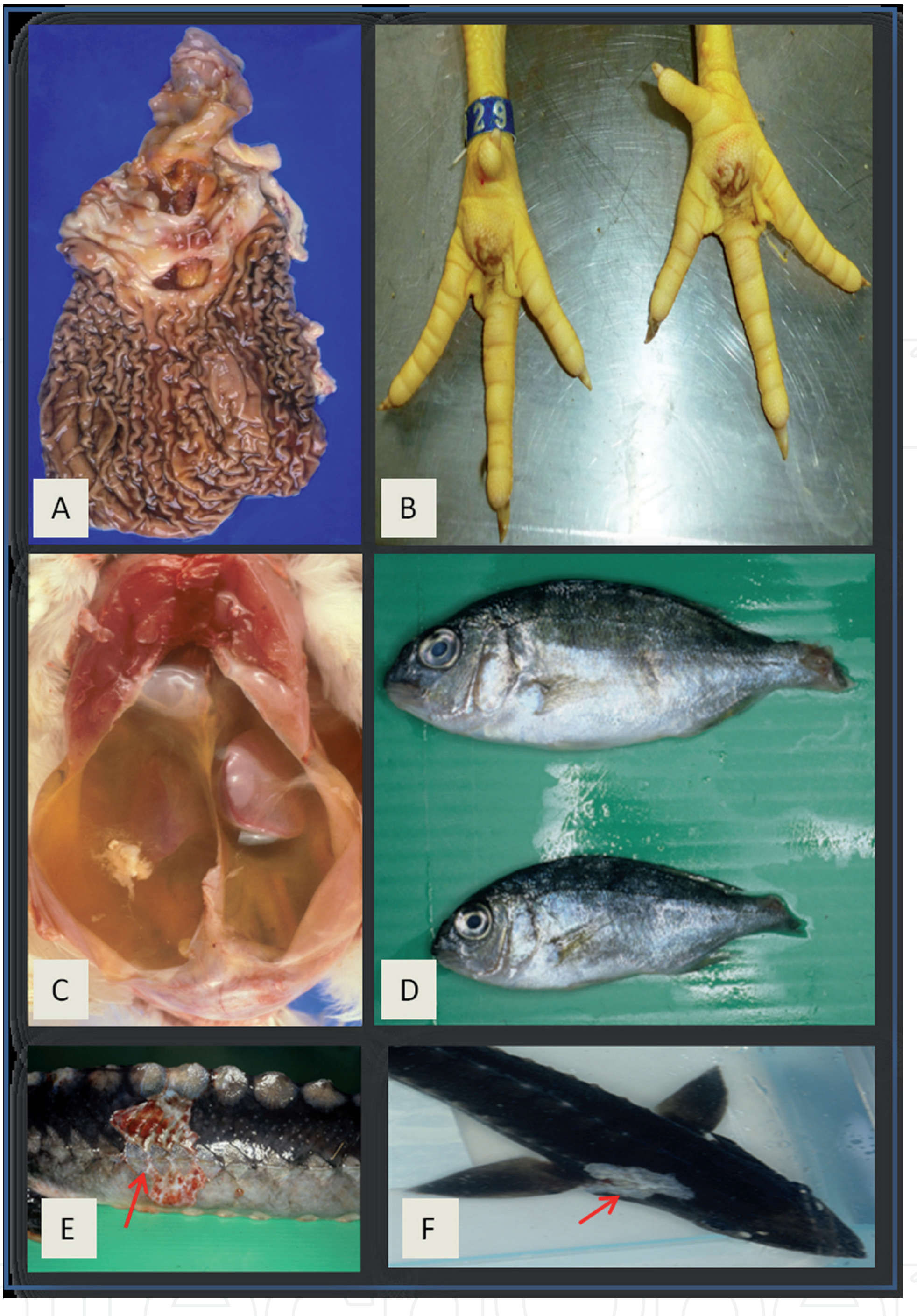

Figure 4.
(A) Horse—gastric ulcer due to improper nutrition. (B) Chicken—footpad dermatitis. (C) Chicken—ascites. (D) Sea bream (Sparus aurata)—peduncle mutilation caused by bite in overcrowding breeding conditions. (E) Sturgeon (Acipenser spp.)—skin erosion caused by an inappropriate and traumatic manipulation. (F) Sturgeon (Acipenser spp.)—dark color and a skin whitish patch due to Flavobacterium spp. infection. Evidence of stress and opportunistic infections.

of carbohydrates causes a rapid proliferation of the hindgut gram-positive bacteria *Streptococcus bovis* and *Streptococcus lutetiensis* that lead to very acidic conditions with pH lower than 4. Low pH in the large intestine causes the death and lysis of a large number of bacteria and the release of the toxic components which are absorbed from the gut into the bloodstream and may cause the development of **laminitis** [21].

2.4 Poultry

The concept of "disturbed habitat" in poultry farming can be almost entirely related to the continuously increasing production levels of the breeding programs, which are focused on increasing the growth rates and decreasing the feed conversion ratios of the animals. These *management procedures* lead to remarkable imbalances between the high potential productivity of birds (as a result of the targeted genetic selection) and their ability to physiologically adapt. These imbalances are frequently associated with homeostatic dysregulation and pathological changes of organs that supply the energy for production and maintenance (liver and cardiovascular system) or muscle tissue severely forced to obtain a fast weight increase. The other "disturbed habitat" conditions may strictly depend on microclimate alterations or management defects related to housing system and degree of social interactions.

With regard to the *microclimate* alterations, heat stress is the most common physical environmental stressor that can lead to alterations in the intestinal epithelium integrity and microbiota composition (with development of necrotic enteritis), hyperthermia, heat exhaustion, and death [22, 23]. Multiple behavioral, physiological, and health issues, such as reduced feed consumption, neuroendocrine disorders, electrolyte imbalance, and systemic immune dysregulation, which in turn will negatively affect nutrient uptake and utilization, growth, and survival rate, are also frequently observed. Modern broiler hybrids seem to be particularly susceptible to heat stress, since the high body heat resulting from their great metabolic activity may exacerbate this phenomenon [23]. Metabolic disorders resulting from other microclimate alterations (such as cold, hypoxia, and light/dark hour changes) are less frequent and quite nonspecific [22].

Management defects related to *housing conditions* and *social interactions* among animals are strictly related to each other. One of the most frequent welfare problems in broiler chickens is **contact dermatitis** (i.e., hock burns, breast burns, and foot pad dermatitis), which is caused by continuing contact and pressure of the skin of the breast, hocks, and feet against humid and soiled bedding. In particular, **footpad dermatitis** (FPD) has the greatest relevance (**Figure 4B**). It is also known as pododermatitis and represents a condition that is characterized by inflammation and necrotic lesions, ranging from superficial to deep on the plantar surface of the footpads and toes. Deep ulcers may also lead to abscesses and thickening of underlying tissues and structures. Several environmental factors such as litter material, moisture depth and amendments, drinker design and management, and stocking density may influence FPD development. Indeed, a straw, wet, thin, and acidifier-added litter and small drinker cups and higher stocking densities have been reported to be associated with a greater incidence of FPD [24]. **Feather-pecking**, which is defined as a nonaggressive behavior whereby birds peck at and/or pull out the feathers of conspecifics, represents one of the most significant welfare concerns in laying hens resulting in feather damage, feather loss, wounds, pain, cannibalistic pecking, and death. Development of feather-pecking has been associated with different causative factors, one of the most important being the inhibition of foraging behaviors (such as ground-pecking or lack of environmental stimuli) and lack of early life access to litter [25].

The selection procedures focused on a high growth rate may cause specific diseases of the energy-supplying organs (in particular the intestine and the liver), as a result of the developing imbalances between oxygen supply and oxygen requirement. In particular, **fatty liver-hemorrhage syndrome** (FLHS) is frequently observed in laying hens, while broiler chicken gut may show malabsorption syndrome [26] . High growth rates, as well as high body weights and low levels of activity, are also frequently associated with the development of lameness of various degrees of severity. It is most prominent in rapidly growing males, with **leg deformities** such as angular bone deformity (valgus-varus), dyschondroplasia, and spondylolisthesis (kinky back) accounting for 65–80% of the noninfectious causes of lameness in broiler chickens. Modern fast-growing strains may also present an increase in skeletal muscle myopathies, such as **white striping** and **wooden breast.** In turkeys, focal avascular or ischaemic necrosis (osteochondrosis) of articular cartilage, avulsion fractures and ligament damage at the intertarsal joint or femorotibial joints, and spontaneous fracture of the femur may also occur [21]. Finally, **pulmonary arterial hypertension** (PAH, also known as ascites syndrome and pulmonary hypertension syndrome) is one of the most common diseases observed worldwide in fast growing broilers (**Figure 4C**). This disease can be attributed to the fast growth-related imbalances between cardiac output and the anatomical capacity of the pulmonary vasculature to accommodate ever-increasing rates of blood flow, as well as to an inappropriate degree of constriction maintained by the pulmonary arterioles. Other common **cardiovascular diseases** associated with rapid growth are the sudden death syndrome (SDS) in broilers and hypertrophic cardiomyopathy (HCM), spontaneous turkey cardiomyopathy (STC), and aortic dissecting aneurysm in turkeys [22].

2.5 Fish

Fish class is the biggest and the most differentiated among vertebrates. Fishes are adapted to different extreme situations as their evolutional success depends on their ability to thrive in a variable medium: water. One of the most remarkable examples of the strict connection between fishes and water is the fishes' inability to regulate their internal temperature (ectothermic animals). Nowadays aquaculture is one of the more sustainable and economically favorable sources of animal protein. Studies on the effect and pathological results of the fishes' "disturbed habitat" are well known due to common compromised (naive) situations. Considering wild habitats, we must sentence that they are strongly impacted by human activity (pollution, overfishing, and introduction of non-indigenous organisms), and this makes it difficult to define what is to be considered normal, not normal, or sub-normal for fishes in a specific situation. In farmed animals, the effect of "disturbed habitat" can sometimes become more evident and dramatic than into the wild [27]. Moreover, the severity of a given disease is dependent on the intricate interaction of numerous variables of the host, the pathogen, and the environment, among which the environment is the less-known factor [28]. In addition, early signs of suffering in fishes are difficult to relate to a specific disease by inexperienced staff. Commonly, acute stressed fishes show color changes because the melanin pigmentation in skin is under neuroendocrine control in fish and it is thus affected by hormones such as epinephrine involved in the first step of stress reaction. If a stress factor persists for a longer time, other hormones, such as cortisol, become dominant (chronic stress). The chronic stress induces immunodeficiency that causes a higher incidence of opportunistic disease outbreaks. Despite the difficulties explained above, in the following section, we will focus on the main stress factors that can impact fish welfare.

Among *abiotic ambient factors,* there are all the physical and chemical water parameters such as temperature, conductivity, salinity, turbidity, hardness, dissolved oxygen and other gasses, pH, ammonia and other nitrogen compounds, metals, pesticides, etc. Fishes can handle an open range of variations for each parameter without showing recognizable signs of disease or suffering, thus accumulating chronic stress. Out of these ranges, water quality parameters can influence acute stress along with **high mortality** showing or not respiratory symptoms. More frequently, considering the synergistic effect of water-quality parameters, only subclinical evidences like a **reduction of productivity and reproduction, dissimilarity of age classes** (for wild stocks), or a higher impact of some **infectious agents or tumors** (if a carcinogenic pollutant is suspected) can be noted [29]. Focusing on the farm self-pollution, due to organic wastewater and nitrogen compound discharge (e.g., ammonia), a direct **damage at the fish gills** (acute gill disease) is evident due to a decreased dissolved oxygen. This acute gill disease is easily detected in fishes with an acute respiratory distress shown by a higher frequency of gill opercula movements. On the contrary, in case of prolonged mild problems, fishes develop a "chronic gill disease" characterized by a fusion of secondary lamellae [30] and a typical fish silhouette called "snake head shape" due to the contrast between a large and triangular head, deformed for the enlarged opercula, and a thin body. In fact, the low level of oxygen blood saturation causes a growth failure for the inability to optimally metabolize food nutrients.

The *housing system* in aquaculture management must take into consideration the different biology, ecology, and natural behaviors of individual fish species. The space, design, composition material for tanks, pools, basins and nets, water source, flow and change, lighting and photoperiod, etc. must be taken into account. An inappropriate housing system determines lower growth performances and a higher incidence of **opportunistic diseases** due to chronic stress [31]. The *degree of social interaction* among fishes, with the main critical point of the animal density, is different in extensive farming when compared to the intensive one: the first is closer to a wild condition while the second is richer of health-limiting conditions. In nature, high animal density happens only for short times (i.e., migration for the reproduction or for feed) but in farmed fishes is a constant need. Over-density causes **traumatic lesions by bite** (skin erosion, ulcers, and body mutilation) (**Figure 4D**) and fast deterioration of water-quality parameters. Similar consequences can be observed as a result of *husbandry practices*, such as selection, artificial reproduction, handling, transport, and net confinement, especially if carried out without suitable tools or by unskilled workers (**Figure 4E**). **Infections** caused by opportunistic bacteria or fungi (Oomycetes) such as *Flavobacterium* spp., *Columnaris* disease (fin or skin rot), or *Saprolegnia* spp. (water mold infection) can develop into skin or gill injuries (**Figure 4F**). Sometimes, if fish density is high and the water quality and exchange low, **parasites** such as barnacles or motile ciliates can also provoke a massive outbreak with evident skin hemorrhages and erosions. At the same time, also common aquatic bacteria such as motile *Aeromonas* spp., *Pseudomonas* spp., or *Vibrio* spp. can cause septicaemia characterized by skin, gills, and internal organ hemorrhages, pop eyes, and skin ulcerations. Regarding feeding, as fish are ectothermic, periods of food deprivation may be less detrimental than in endotherms. For this reason, temporary starvation prior to transport, treatment of disease, or any other kind of handling procedures is highly recommended to reduce physiological stress [27]. However, an inappropriate food composition or feeding procedure can generate **gut problems** like enteritis and **size inhomogeneity** in the fish stock [32].

3. Zoo and wild animals

The literature merges concepts and definitions of modern zoos and aquaria as "centers for education and conservation." In this sense, their animals are considered as "ambassador guests" or even stakeholders of the zoological institutions. Husbandry procedures impact directly on the welfare of every managed animal species and should be carried out with "human care" regardless of the context, artificial, semi-natural, or wild; this highlights the importance of precise estimation of the resources provided to the animals, by humans.

But, is this always the case? Advocacy groups often claim that animals would only live a good life "worth living," if they were left into the wild. In reply to this controversy stands the extremely relevant anthropic detrimental influence on the environment and a precise definition of "ex situ" as: "conditions under which individuals are spatially restricted with respect to their natural spatial patterns or those of their progeny, are removed from many of their natural ecological processes and are managed on some level by humans" [33].

This concept has created a lot of confusion in the years, on whether the artificial environment could really provide excellent welfare conditions, to be evaluated directly on each individual. Welfare indicators in fact, vary among and within species, and depend directly on human interests and uses of them. This is particularly true for nondomestic species where individual case relevance is rare, fragmented, and often requiring comparison with their wild counterpart.

For this reason, modern zoological institutions tend to mimic the irreplaceable wildlife observations and provide the animals with environmental resources extrapolated from previous *ex situ* experiences and consolidated in best practice guidelines [34]. Careful attention is paid to *animal management processes*, starting from animal acquisition and transport, quarantine and acclimation, and introduction into social group. Exhibits with multiple species must take into consideration social compatibility, both intra and interspecific. The density and distribution of most species should be compatible with the space provided, allowing the expression of natural behaviors and guaranteeing individual safety, thus avoiding **undesired dominance and aggression** [35].

Zoo and aquarium "artificial habitat" construction takes into consideration the preparation of controlled microclimate systems [35]. For example, indoor air temperature, ventilation, and filtered aeration prevent transmission of **respiratory pathogens** (*Aspergillus* spp., *Mycobacterium* spp., etc.) in most air breathing species. Appropriate lighting and photoperiod allow a natural circadian rhythm to regulate hormonal cycles, reproduction, and molt in most species [36]. For aquatic and semi-aquatic species, the installation and management of "Life Support System" provides computerized systems to control filtration, disinfection, and chemical/physical water parameters suitable for the species maintained. Mechanical filtration removes particulate solid matters and the complex system of biological filtration avoids direct contact with all the toxic compounds originating from nitrogen life cycle. Water temperature control is mandatory since it could literally limit survival of species originating from different climates. Inappropriate levels of pH, salinity, and hardness might lead to **chronic stress** or even death. Water disinfection and oxidation must be under strict control to avoid damages or losses from accidental increased redox potential, lethal for fish and invertebrates, and seriously **damaging skin and eyes** of aquatic reptiles and mammals [37].

Health affects the animal's welfare and the quality of its life. Veterinary programs address general and specific issues such as nutrition, reproduction, and management of geriatric individuals. *Unbalanced diets* can lead, for example, to **abnormal growth, gout,** or **hypovitaminosis**, to even impossibility to thrive [35]. Poor fitness affects breeding and lifespan, but also physical appearance and behavior of the individuals, influencing the human perception of their role for conservation or "ambassadors of the species." Zoos and aquaria maintain animals in good physical, social, and mental health, to fulfill their mission and promote *ex situ* conservation.

Wildlife is also strongly influenced by human impact on the environment, only from a different perspective. The correlation between "disturbed habitat" and pathology is in fact not always clear, nor evident for wild animals: disease and death are in fact processes of the normal circle of life, and can be considered as unnatural problems only when caused by human interference. As stated by the World Association of Zoo and Aquaria in Caring for wildlife (2015) [38]: "we affect animals by destroying their habitats, polluting their environment, introducing invasive species into their ecological systems, building structures in flight-paths, tilling the land, cutting trees, driving cars, burning fuel, and on and on…."

An increased food demand, an intensification, and mechanization in agriculture, including use of chemical products, led to a widespread decline in farmland biodiversity and remarkable change of landscapes and habitats. The use of pesticides facilitates farmers' work, thus menaces the environment and its living creatures. In the European rice fields, the butterfly *Lycaena dispar*, an important environmental indicator, is in decline due to the massive use of herbicides; and similar events occurred in Japan as well [39]. "The European Red List of Saproxylic Beetles" (2018) [40] highlights the importance of these beetles in the forest ecosystems and their dependence on dead and decaying wood. They are involved in numerous processes but often ruined by the wrong perception that deadwood is a sign of neglected forest management.

The effects of climate warming are recognized by everyone and lead to desertification in many countries, provoke unprecedented disastrous events, and affect ecosystems and species survival around the world, including our own. Glaciers melting at an increasing speed directly affect polar bears (*Ursus maritimus*) and Arctic environment, leading to disappearance of their habitat and food resources.

Invasive species became a very relevant problem [41]: the gray squirrel (*Sciurus carolinensis*), introduced in the last century in Europe, is a threat to the native red squirrel (*S. vulgaris*). Gray squirrels compete for resources and, in Britain, are a reservoir for a virus highly pathogenic for red squirrel, inducing a disease-mediated competition between the species. Other countries could face the same problem in future: in Japan, *S. vulgaris* is a common pet with high risk of uncontrolled release and impact on the native *S. lis* [42]. The introduction of the popular American pet red-eared slider caused similar threats imposing major conservation activities to preserve the native European pond turtle [43].

Artificial lights can affect plant's photosynthesis, circadian rhythm, visual perception, and spatial orientation and can disorient many nocturnal species. Preys around lamps attract bats that also become more detectable by birds of prey. New road constructions are welcomed with enthusiasm, but they fragment habitats and represent insuperable dangerous barriers for crossing animals.

Coexistence between domestic and wild species can spread **transmissible diseases**. Infectious keratoconjunctivitis originates from infected livestock and passes to alpine chamois (*Rupicapra rupicapra*) and alpine ibex (*Capra ibex*) that graze close to each other. Another type of challenge is represented by the return of wolves in the Alps, since farmers do not tolerate their predation on livestock. The authorities promote preventive measures and compensation for the damage, but the conflict is strongly due.

Overexploitation of natural resources is a worldwide-recognized problem and animal collectors have a huge impact on biodiversity. Oriental medicine utilizes parts of wild animals (tigers, rhinos, sharks, seahorses, etc.). The indiscriminate fishing of the totoaba, a very popular fish, whose swim bladder represents an unremarkable black market value, has brought the small cetacean vaquita on the verge of extinction.

Finally, in the last decades, humans developed new types of sports and touristic attractions with animal direct contact and experience. As an example, ski mountaineering, a dangerous and exciting popular sport in the Alps, can be lethal for alpine animals, such as the black grouse (*Tetrao tetrix*) or rock ptarmigan (*Lagopus muta*). Photo safaris and the desire to "get closer" to wilderness, at all costs, are a growing "leisure product" which is very disgraceful to nature.

4. Conclusion

In 1915, Cannon defined stress as a "perturbation of the homeostasis, the coordinated physiological process which maintains a steady state in the organism" [44]. A persistent stress condition may result in psychological and physiological pathology.

From the perspective of domestic/wild animals, these pathologies may occur at a clinical or subclinical level and may manifest as altered behavior, decreased immune protection that impacts disease susceptibility, or altered metabolism that impacts either growth, production, or a combination of these responses.

This chapter represents a non-exhaustive list including only a few examples of scientific evidence that farm animals or wildlife face multiple threats related to stressing factors/habitat disturbance, by direct or indirect human impact on the environment. While it is clear that we have been the major cause of these dramatic changes, we are also growing a generalized protective conscience towards natural resources. A virtuous search for new technologies and alternative human behavioral changes is now mandatory to minimize our impact and foster our survival on this planet [45, 46].

In this contest, animal welfare relates to more than merely the physical health of an individual. Animal welfare means how an animal is coping with the conditions in which it lives [47]. An animal is in a good state of welfare if it is in an appropriate social context, healthy, comfortable, well nourished, safe, able to express innate behavior, and if it is not suffering from unpleasant states such as pain, fear, and distress. Good animal welfare requires disease prevention and veterinary treatment, appropriate shelter, management, nutrition, humane handling and, ultimately, humane slaughter. Animal welfare refers to the state of the animal and protecting an animal's welfare means providing for its physical and mental needs [8].

In recent years, a great and growing attention is paid to the aspects of health and welfare of reared animal species. For farm animals, the initiative of people to care about the welfare of farm animals is based on their moral attitude and concern for the right and wrong treatment of animals, with presumed opposition to overexploitation and/or cruelty towards animals [48]. There is also growing concern for many consumers in Europe about farm animal welfare since it is becoming increasingly recognized as an important attribute of food safety and quality [48, 49]. To enhance animal welfare, a first essential step is to help animals to cope with their environment. Two different approaches can be used: firstly we propose to adapt the environment to the animals by improving management practices and housing conditions. This approach requires the active involvement of all stakeholders: veterinarians, behaviorists, animal scientists, the industrial farming sector, the food processing and supply chain, and consumers of animal-derived products. Secondly, we can create rearing conditions that better "prepare" animals for the environment in which they will be kept in later stages of their life.

Also for zoo animals, as habitats and ecosystems become increasingly altered and populations evermore impacted by human activities, a growing number of species will require some form of management of both individuals and populations to ensure their survival. Zoo and aquaria aim to fulfill this role. Whereas zoos and aquariums of the past were places where animals were "displayed" for the pleasure of visitors, today's zoos and aquariums are centers for conservation. They must ensure that the conditions for animals in their care are the best that can be delivered, providing environments that focus on the animals' physical and behavioral needs. To accomplish this, it is necessary to make sure that animal care staff have relevant scientific training and expertise, developing and maintaining a staff culture that practices regular reporting and monitoring of animals' behavior and health, employing veterinarians, biologists, welfare scientists, and behavioral experts, introducing different enrichments that provide challenges, choices, and comfort to animals to maximize their psychological health. In fact, the major features of animal welfare that are relevant to zoos and aquariums merge the following aspects: meeting animals' basic survival needs for food, shelter, health, and safety and enhance their welfare above this survival minimum by increasing opportunities for animals to have positive experiences, focused, for example, on their comfort, pleasure, interest, and confidence. Although visitors' direct impact on animal welfare is limited, their expectations have risen sharply and support the zoo and aquarium commitment to keep animals healthy and engaged, by also utilizing environmental enrichment skills [38].

To conclude, considering the enormous number of animals whose life conditions are affected by human habits, all possible efforts can and must be made to improve their status in order to ban welfare-compromising procedures and practices as soon as possible.

Conflict of interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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