Chapter 4

The Use of Genetically Modified Organisms for Repopulation of Species of Commercial Importance in Aquatic Environment: Effects on Genetic Pool, Risks to Protected Areas and Policies for Their Proper Management

Maurilio Lara-Flores and Evelia Rivera-Arriaga

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.76441

Abstract

In recent years, the reproduction of organisms through genetic engineering has been presented as an option for the repopulation of fish stocks of species that are at the limit or have passed their maximum sustainable exploitation. However, are the potential effects on genetic diversity known? The possible mutations? The risks to protected ecosystems? or Are there adequate policies and regulations for its management? This chapter aims to review the biological and population effects of the use of these organisms and the potential impacts they can cause to natural protected areas, as well as if there are adequate regulations or policies for their use. Finally, the authors give indicators for the sustainable integrated management of genetically modified organisms.

Keywords: genetically modified organisms (GMOs), aquatic environment, risks, policies, management

1. Introduction

Over the past 30 years, biotechnological developments have allowed scientists to alter the genetic make-up of bacteria, plants, and animals. At the beginning, the modifications had the purpose of carrying out basic research (the function of the gene and the mechanisms of genetic transfer); however, these techniques were quickly transformed into tools for use in agricultural activities, since they allowed adding new characteristics to organisms in order to increase their capacities to be used in extensive monocultures (e.g., animals with a better neonatal survival or plants with herbicide resistance). The first genetically modified organisms (GMOs) were introduced in 1996, and currently around 200 million hectares are GMO crops worldwide [1, 2].

With the creation of the first genetically modified (GM) [3], various efforts have been made to modify the characteristics of farm animals to increase their production. Among the most studied characteristics are the increase in fertility [4], resistance to diseases [5], growth rate [6], and the reduction of the impact of activity to the environment [7].

An important source of protein for most people on the planet is products of marine and freshwater origin; these are mostly obtained through fishing; this activity causes serious consequences to the environment. The development of new fishing gears and the increase in the exploitation of aquatic species of commercial interest, together with the needs to supply the population with quality food, has prompted that in recent years this resource is at its maximum sustainable for its exploitation. Many populations of aquatic organisms are already overexploited, and their environmental and economic viability threatened in the medium term are considered. Genetically modified aquatic organisms are considered an option to increase the performance of aquaculture and as a means of repopulating natural stock; however, Italia use has generated a general concern for the possible impact on wild species with the consequent environmental damage [8].

Australia is the pioneer country in developing genetically modified aquatic organisms. Currently, the Maine Research in transgenic aquatic organisms has been developed in the United States, Canada, Cuba, China, and New Zealand. However, and despite biotechnological advances, many of these GMOs have only been used in aquaculture due the insecurity of the harmful effects on wild populations and the ecosystem [9].

This work aims to review the biological and population effects of the use of these organisms and their potential impact to natural protected areas, as well as if there are adequate regulations or policies for their use.

2. Genetically modified organisms

Genetically modified organism (GMO) refers to the organism in which there has been alteration of genetic material. GMOs are transgenic organisms into which desired DNA is inserted and incorporated with the help of *in vitro* techniques of genetic engineering.

The first transgenic animal was a mouse [10]. Rainbow trout [11] and goldfish [12] are the first transgenic production in aquatic species. Some of the significant species that today produced as GMO are Atlantic and Coho salmon, Tilapia species, catfish, medaka, and zebrafish.

For the development of GMO requires a series of steps to ensure its proper development. The steps can be summarized as follows: (a) identification of the gene of interest, (b) insolation of the gene, (c) amplification of the gene, (d) insertion of the gene in appropriate plasmids, (e) the plasmid is cloned in bacteria to multiply it and be able to be injected, (f) the plasmid is inserted into the recipient tissue, normally fertilized eggs, (q) the gene is integrated into the receptor genome, (h) and finally the gene is expressed in the genome of organisms and is transferred to subsequent generations [9].

3. Ecological and genetic effect of transgenic aquatic species

Releases of genetically engineered organisms may directly or indirectly lead to changes in the natural environment. According to Williamson et al. [13], the environmental effects may be divided into three broad categories: (1) effects caused by the genetically engineered organism itself, (2) effects resulting from dispersal of genes from genetically engineered organism to other organisms in the environment, and (3) altered practice in the use of an organism because of the genetic modification.

The scale and frequency of introductions of transgenic aquatic species into a particular environment will greatly influence the degree of ecological risk involved [14]. According to Beardmore and Porter [14], the type and degree of ecological risk will vary depending on a number of factors: (a) the type of transgenic aquatic organisms, namely the overall phenotypic effect of the transgene, (b) the adaptive ability of the transgenic animals to the local environment, (c) the fitness of the transgenic fish, (d) the health of local populations, (e) the normal ecological role of the host species, (f) the potential for dispersal and persistence, and (g) the local environment itself.

The effects of GMO on wild ecosystems can be divided into two types [14, 15]:

a. *Intraspecific interactions:* the greatest ecological risk that GMOs can cause is the impact on the native populations of the ecosystem. The release to the environment of GMOs in order to increase their populations can cause a reproductive interaction between individuals of the same species, with what can cause a modification of the original genome of the species. If natural population comes to acquire the new genes, this can be translated into the loss of natural aptitudes and adaptations, for example, the resistance to diseases or the reduction in the anti-depredator response [15].
b. *Interspecific interactions:* an ecological risk associated with the introduction of GMOs to the environment is the impact on the aquatic communities with which it interacts. GMOs represent a risk within ecological niches and species. This is due to the competition between the species, mainly due to the possible aggressive behavior toward other individuals. This could lead to the destruction of target organisms of other species, the generation of new competitions for resources with other species, or the de-targeting of the specific habitat to one or several species, all this with the consequent imbalance of the ecosystem [14].

It is considered that GMOs cause a minimal risk to the environment, since many of these are modified for use under controlled conditions in farms or domestic use. On the other hand, it is considered that GMOs that are used under controlled conditions will not survive in the environment without human help. However, it is necessary to evaluate the environmental risk that they can cause in case there could be a genetic exchange between the GMOs and the unaltered organisms that live naturally in the environment [16].

The effects caused by GMOs usually depend on the characteristics of the species, the environmental conditions, and the lifespan on the organisms. When evaluating the effects of GMOs, it should consider not only the effects in the same species but also the possible affectations to other species and the environment, this being the case that as GMOs and their genes can traverse in time and space. Therefore, it is essential to have all the documented information possible about environmental effects if you want to release a GMO, although it is practically impossible to predict such effects. On the other hand, it must be considered that GMOs can evolve for adaptation in the environment or for natural selection [17].

In the last years, research is being developed to create new transgenic fish in order to repopulate the natural water and for production purposes in farms. These investigations have been focused mainly to increase the speed of growth, size, resistance to diseases, and an increased survival in extreme habitats or in the face of climate change. In the environment, GMOs can be established permanently and irreversibly, with important effects on aquatic communities. Currently, mass gene transfer techniques such as lipofection, particle bombardment, and the electroporation of embryos and sperm cells are being developed and perfected in order to modify large batches of ovules [18]. The controversy about the release of GMOs to the environment has been widely discussed in the scientific and political environment [16, 19, 20]. In general, it has been observed that GMOs in the aquatic environment suffer from a greater predation [20], changes in eating habitats [21], a greater ability to compete for food [22], and better swimming skills [23].

To date, it is considered that the investigations to ensure the release of GMOs to the environment present sufficient sustenance to avoid damaging the environment; however, it is necessary to take into account that each GMO must be studied differently since its effects in the environment may vary [24, 25]. A clear example of the above has been observed in GMOs of plant origin where resistance to insects has been transferred from the cultivation areas to the wild areas causing significant losses in the production of honey [26, 27]. The effect that GMOs can cause in the environment is not known; however, it has been inferred that they could unbalance the ecosystem mainly at the trophic level due to the disappearance of species or the appearance of new diseases.

4. Management

Animal genetic resource for food provides an important element for sustainable development as well as for food security. However, this resource is poorly managed with dramatic consequences to local biodiversity, especially to the livestock sector. According to the Food and Agriculture Organization of the United Nations (FAO) [28] *"the biodiversity of the 35 or so animal species that have been domesticated for use in agriculture and food production is the primary biological capital for livestock development and is vital to food security and sustainable rural* *development. Many indigenous breeds, some of which are threatened with extinction, have characteristics such as resilience to climatic stress and resistance to diseases and parasites, which make them well adapted to local conditions, and which are of great potential importance to future livestock production."* Also, FAO performed a balance of livestock which provided a comprehensive assessment and trends. It is important to enhance production conditions on the few breeds that are exploited worldwide, and that suffer from a high concentration of livestock development; otherwise, these may impose survival, production, and reproduction disadvantages for those animals. According to The State of the World's Animal Genetic Resources for Food and Agriculture [29], "twenty percent of documented livestock breeds are at a risk of extinction: 1500 of the 7600 breeds around the globe may be lost forever in the near future."

In relation to accidental introduction or the release of GMO in the wild, cause dispersion to other sites or even breed with individuals forms other wild populations. This fact continues to cause ecological concern globally, but there have been no published reviews of their effects in Mexico. Impacts in Mexico are therefore in need of a review, along with current legislation and guidelines relating to the introduction and control of such species.

To this day, it is impossible to assess the number of modified animal species that have been introduced to the wilderness in Mexico, both deliberately and accidentally, but only a small number of introduced GMO may suggest some degree of ecological impacts. However, to this point, it is difficult to consider that in Mexico, biodiversity may be negatively affected, and the potential effects of future climate change, and an increased number of genetically modified organisms may invade susceptible ecosystems. In this scenario, detrimental impacts if genetically modified organisms on native biota may occur through competition, predation, herbivory, habitat alteration, disease, and genetic effects (i.e. hybridization). In addition, there are potential effects on genetic biodiversity as well as species biodiversity.

Management measures for the control of potential negative effects on wild fauna might be more feasible if genetically modified animal organisms could be identified at an earlier stage of establishment. Nevertheless, it is very difficult to characterize modified organisms in the wild, and it is harder to foresee any impact that they may impose on ecosystems or wild populations. The difficulties of making general predictions suggest that every proposed organism introduction in the wilderness should be subject to rigorous ecological and sanitary characterization and risk assessment prior to introduction.

The nearly absence of Mexican legislation and guidelines developed on this matter to reduce impacts of genetically modified organisms into the wilderness is a critical gap that should be addressed as soon as possible. But still, to have this type of legislation is only part of the way toward ameliorating environmental impact. Many organisms already established in the wild might cause future problems. Illegal releases and escapes of genetically modified organisms may augment health and sanitary problems. While regulation of imports and releases is important, further enforcement of existing legislation and action against unlicensed releases is necessary.

Highly genetic manipulation and interbreeding, besides poor management, may result in antimicrobial resistance which poses a fundamental threat to human and animal health, development, local and national economy, as well as security. There are high levels of antimicrobial resistance due to overuse and misuse of antibiotics and other antimicrobials in both

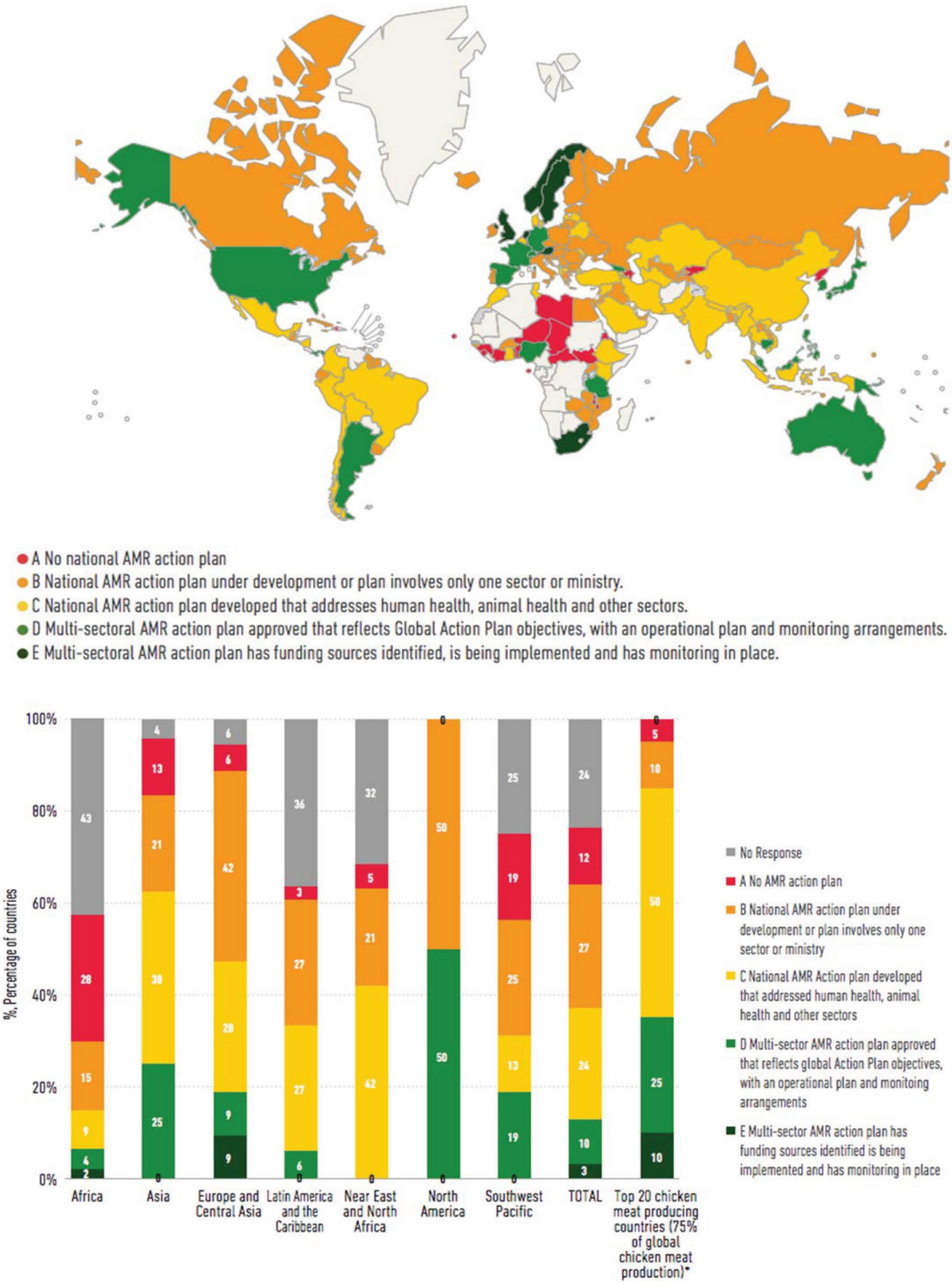

Figure 1. Country progress with the development of a national action plan on antimicrobial resistance as of May 29, 2017 [31].

humans and animals, including farmed fish and aquatic organisms, as well as residues of those drugs in the environment. The World Health Organization (WHO), FAO, and World Organization for Animal Health (OIE) have launched a Global Implementation Action Plan on Antimicrobial Resistance, with specific actions by May 2017 [30].

As of May 29, 2017, 147 countries had responded to the questionnaire (**Figure 1**). The overall findings show that countries have made significant progress in developing national action plans and implementing actions in the human and animal health sectors, in crop production, food safety, and the environment. Responses from countries also highlight areas where specific assistance and support are required [30].

From a new perspective, Laikre et al. [32] stated that "Large-scale exploitation of wild animals and plants through fishing, hunting and logging often depends on augmentation through releases of translocated or captively raised individuals." Such releases are performed worldwide in vast numbers. Augmentation can be demographically and economically beneficial but can also cause four types of adverse genetic change to wild populations: (1) loss of genetic variation, (2) loss of adaptations, (3) change of population composition, and (4) change of population structure. While adverse genetic impacts are recognized and documented in fisheries, little effort is devoted to actually monitor them. In forestry and wildlife management, genetic risks associated with releases are largely neglected.

Moreover, Mandel [33] in his review considered that the "regulation system of genetically modified organisms is far behind from biotechnology advances, which makes it passive rather than proactive about risks; difficult to adapt to new technology; and it is highly fractured and inefficient."

All these expose both the environment and the society to unnecessary risks that put difficult challenges to regulatory and management systems as well. These risks and inefficiencies include gaps in regulation, duplicative and inconsistent regulation, unnecessary regulatory expense, multiple agencies acting outside their areas of expertise, and unnecessary increase in the institutional, social, and environmental costs.

5. Conclusion

Ecological effects and the geographic ranges of organisms transcend political boundaries; therefore, we consider it essential to promote and achieve international coordination of risk assessment and regulation of biotechnology. Because the potential hazards of GMO are often environment-dependent, and ecosystems and biotas vary geographically and climatically, an organism that is safe in one country is not necessarily safe in other. Thus, both the commercial import and export and the inadvertent dissemination of GMO or their genes across political boundaries present special concerns that require cooperation and coordination. Special consideration must be given to the protection of rare genetic resources, such as the wild ancestors of domesticated species and threatened gene pools of other wild species. We urge local, state, national, and international cooperation in regulation, risk assessment, and risk management of the ecological effects of the introduction of GMO.

Author details

Maurilio Lara-Flores* and Evelia Rivera-Arriaga

*Address all correspondence to: maurilio_lara@yahoo.com.mx

Insituto de Ecología, Pesquerias y Ocenografía del Golfo de México, Universidad Autónoma de Campeche, San Francisco de Campeche, Mexico

References

[1] James C. A global overview of biotech (GM) crops: Adoption, impact and future prospects. GM Crops. 2010;**1**:8-12

[2] James C. Global Status of Commercialized Biotech/GM Crops: 2011, Vol. 43 of ISAA Brief. Ithaca, NY: ISAAA; 2011

[3] Hammer R, Pursel V, Rexroad C, Wall R, Bolt D, Ebert K. Production of transgenic rabbits, sheep and pigs by microinjection. Nature. 1985;**315**:680-683

[4] Tong J, Wei H, Liu X, Hu W, Bi M, Wang Y. Production of recombinant human lysozyme in the milk of transgenic pigs. Transgenic Research. 2011;**20**:417-419

[5] Lyall J, Irvine R, Sherman A, McKinley T, Nunez A, Purdie A. Suppression of avian influenza transmission in genetically modified chickens. Science. 2011;**331**:223-226

[6] Devlin R, Sakhrani D, Tymchuk W, Rise M, Goh B. Domestication and growth hormone transgenesis cause similar changes in gene expression in Coho salmon (*Oncorhynchus kisutch*). Proceedings of the National Academy of Sciences of the United States of America. 2009;**106**:3047-3052

[7] Phillips J, Golovan S, Meidinger R, Forsberg C. Transgenic enhancement of nutrient cycling: moving toward and environmentally sustainable animal agriculture. In: Proceedings 8th WCGALP. Minas Gerais, Brazil: Instituto Prociência; 2006. pp. 19-22

[8] Muir WM. The threats and benefits of GM fish. EMBO Reports. 2004;**5**:1-6

[9] Singh A, Deb R, Rajendran N. Benefits and risks of genetically modified organisms in aquaculture. International Journal of Pharmaceutical Sciences Review and Research. 2014;**27**:79-84

[10] Rahman MA, Maclean N. Growth performance of transgenic tilapia containing and exogenous piscine growth hormone gene. Aquaculture. 1999;**173**:333-346

[11] Maclean N, Laight RJ. Transgenic fish: An evaluation of benefits and risks. Fish and Fisheries. 2000;**1**:146-172

[12] Reichhardt T. Will souped up salmon sink or swim? Nature. 2000;**406**:10-12

[13] Williamson M, Perrins J, Fitter A. Releasing genetically engineered plants: Present proposals and possible hazards. Trends in Ecology and Evolution. 1990;**5**:417-419

[14] Beardmore JA, Porter JS. Genetically modified organisms and aquaculture. Food and Agriculture Organization of United Nations. Rome, Italy: FAO; 2003

[15] Gutrich JJ, Whiteman HH. Analysis of the ecological risks associated with genetically engineered marine macroorganisms. In: Genetically Engineered Marine Organisms: Environmental and Economic Risks and Benefits. Boston, USA: Kluwer Academic Publisher; 1998

[16] Muir WM, Howard RD. Possible ecological risks of transgenic organism release when transgenes affect mating success: Sexual selection and the Trojan gene hypothesis. Journal of Fisheries and Aquatic Sciences. 1999;(24):13853-13856

[17] Tiedje JM, Colwell RK, Grossman YL, Hodson RE, Lenski RE, Mack RN, Regal PJ. The planned introduction of genetically engineered organisms: Ecological considerations and recommendations. Ecology. 1989;**70**:298-315

[18] Sin FYT. Transgenic fish. Fish Biology and Fisheries. 1997;**7**:417-441

[19] Hallerman EH, Kapuscinski A. Transgenic fish and public policy: Regulatory concerns. Fisheries. 1990;**15**:12-19

[20] Jonsson E, Johnsson JI, Bjornsson BT. Growth hormone increases predation exposure of rainbow trout. Proceedings of the Research Society of London Biological Science. 1996;**263**:647-651

[21] Abrahams MV, Sutterlin A. The foraging and antipredator behavior of growth-enhanced transgenic Atlantic salmon. Animal Behavior; **58**:993-942

[22] Devlin RH, Johnsson JI, Smailus DE. Increased ability to compete for food by growth hormone-transgenic Coho salmon *Oncorhynchus kisutch*. Aquatic Research. 1999;**75**:335-337

[23] Farrell AP, Bennett W, Devlin RH. Growth-enhanced transgenic salmon can be inferior swimmers. Canadian Journal of Zoology. 1977;**75**:335-337

[24] Dommelen A. Hazard Identification of Agricultural Biotechnology. Utrecht, The Netherlands: International Books; 1999

[25] Ginburg LR. Assessing Ecological Risks of Biotechnology. Boston, USA: Butterworth-Heinemann; 1991

[26] Krimsky S, Wrubel R. Agricultural Biotechnology and the Enviroment. Champagne, Illinois, USA: University of Illinois Press; 1996

[27] Rissler J, Mellon M. The Ecological Risks of Engineered Crops. Cambridge, MA, USA: The MIT Press; 1996

[28] FAO. The Second Report on the State of the World's, Animal Genetic Resources for Food and Agriculture. 2015. Availble from: http://ww.fao.org/3/a-i4787e/index.html

[29] FAO. Global Plan of Action for Animal Genetic Resource and the Interlaken Declaration. 2007. Available from: ftp://ftp.fao.org/docrep/fao/010/a1404e/a1404e00.pdf

[30] FAO. The FAO Action Plan on Antimicrobial Resistance 2016-2020. Supporting the food and agriculture sectors on implementing the global action plan on antimicrobial resistance to minimize the impact of antimicrobial resistance. 2016. Available from: http://ww.fao.org/3/a-15996e.pdf

[31] FAOSTAT. Food and Agriculture Data. 2018. Available from: http://www.fao.org/faostat/en/#home

[32] Laikre L, Schwartz MK, Waples RS, Ryman N. Compromising genetic diversity in the wild: Unmonitored large-scale release of plants and animals. Trends in Ecology & Evolution. 2010;**25**:520-529

[33] Mandel GN. Gaps, inexperience, inconsistencies, and overlaps: Crisis in the regulation of genetically modified plants and animals. 45 Wm. & Mary L. Rev. 2167. 2004. Available from: http://heinonline.org/HOL/LandingPage?handle=hein.journals/wmlr45&div=46&id=&page=