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ETHICAL ANALYSIS OF THE USE OF GM FISH: EMERGING ISSUES FOR AQUACULTURE DEVELOPMENT

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ABSTRACT. Improvements in production methods over the last two decades have resulted in aquaculture becoming a significant contributor to food production in many countries. Increased efficiency and production levels are off-setting unsustainable capture fishing practices and contributing to food security, particularly in a number of developing countries. The challenge for the rapidly growing aquaculture industry is to develop and apply technologies that ensure sustainable production methods that will reduce environmental damage, increase productivity across the sector, and respect the diverse social and cultural dimensions of fish farming that are observed globally. The aquaculture industry currently faces a number of technology trajectories, which include the option to commercially produce genetically modified (GM) fish. The use of genetic modification in aquaculture has the potential to contribute to increased food security and is claimed to be the next logical step for the industry. However, the potential use of these technologies raises a number of important ethical questions. Using an ethical framework, the Ethical Matrix, this paper explores a number of the ethical issues potentially raised by the use of GM technologies in aquaculture. Several key issues have been identified. These include aspects of distributive justice for producers; use of a precautionary approach in the management of environmental risk and food safety; and impacts on the welfare and intrinsic value of the fish. There is a need to conduct a comparative analysis of the full economic cycle of the use of GM fish in aquaculture production for developing countries. There is also a need to initiate an informed dialogue between stakeholders and strenuous efforts should be made to ensure the participation of producers and their representatives from developing nations. An additional concern is that any national licensing of the first generation of GM fish, i.e., in the USA, may initiate and frame an assessment cycle, mediated by the WTO, which could dominate the conditions under which the technology will be applied and regulated globally. Therefore, an integrated analysis of the technology development trajectories, in terms of international policy, IPR, and operational implications, as well as an analysis of a broader range of ethical concerns, is needed.

KEY WORDS: Aquaculture, GM fish, ethical matrix, development, ethical analysis

1. CAPTURE FISHING, AQUACULTURE AND DEVELOPMENT

Fish protein is a valued global food resource. For many in the developing world it is a vital primary source of high quality protein (FAO, 2004a). In

Europe, consumers are actively encouraged to consume two portions of fish per week as part of a healthy diet (Food Standards Agency, 2006). Global consumption of fish has doubled over the last thirty years, with an average per capita consumption rate increase of 12 kg/year to 24.8 kg/year (FAOSTAT, 2004). At current levels, fish protein accounts for 15% of the overall total animal protein consumed worldwide (FAOSTAT, 2004), with fish products now accounting for 20% of animal-derived protein in low-income, food-deficit countries, compared with 13% in developed countries (Delgado et al., 2003).

The major source of fish is still capture fishing, however, current practice is proving increasingly unsustainable. Global marine stocks are diminishing at alarming rates due to over exploitation, thus threatening marine biodiversity. Recent figures from the FAO indicate that fish stocks for a number of major species are at the point of collapse, with 25% of marine species being over exploited and 50% fully exploited (FAO, 2005). This, in turn, is creating economic hardship and impacting negatively on traditional fishing communities across the globe.

These significant concerns regarding marine overfishing, an ever-increasing global market for fish and seafood, and a series of technological innovations have all stimulated increased production from aquaculture.[1] Aquaculture production now accounts for over 30% of the overall marine product markets (fish, molluscs, crustaceans, etc) (FAO, 2003). Although there is a long standing tradition of rearing fish in captive ponds in a number of countries, modern commercial aquaculture has only developed over the last three decades (increasing from 5.3% to 32.2% of the total world fisheries landing between 1970 and 2000; FAO, 2003).

Partly due to diminished returns from captive fishing and the regions that are increasingly employing this form of production method, aquaculture has been characterized as a notable force for social development. Aquaculture has been a highly significant factor in providing local food security, alleviating poverty, improving rural livelihoods, creating employment, and generating income in some of the poorest regions. The potential for aquaculture to reduce poverty and provide food security in many of the world's poorest nations has resulted in modern aquaculture being heralded

[1] When referring to aquaculture, this report is applying the FAO definition (FAO, 2003). Aquaculture: the farming of aquatic organisms, including fish, molluscs, crustaceans, and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated. For statistical purposes, aquatic organisms harvested by an individual or corporate body that has owned them throughout their rearing period contribute to aquaculture, while aquatic organisms that are exploitable by the public as a common property resource, with or without appropriate licenses, are the harvest of fisheries.

as the new technological–blue–revolution. Enhanced aquaculture production has increased the supply of high quality fish protein for rural and urban populations in many developing countries. Unlike the Green Revolution, which brought the majority of agri-food benefits to the world's richest nations, the challenge for the aquaculture industry is to ensure that rapid developments in aquaculture will result in a 21st Century "Blue Revolution" that will convey major benefits to the poorest nations (Aerni, 2004).

However, in addition to concerns that advances may not deliver for the global citizens that most require support and innovation, a number of aquaculture production problems have been identified. Significant concerns have been expressed about: (i) the potential risks associated with environmental impacts from the increased use of pesticides and antibiotics; (ii) discharge of production wastes and pollutants; (iii) ecological impacts from any potential escapees; (iv) frequency and diversity of disease outbreaks; (v) increased wetland and land use impacts, and (vi) reliance on high energy inputs (such as aquafeeds). With the rapid expansion of production there are increasing concerns that production efficiency will be the dominant driver for the industry, at the cost of environmental protection and social justice.

In addition, the global demand for fish is unlikely to wane and in the current climate although a greater quantity of aquaculture fish products will be produced and consumed, the most significant challenge for industry will be not to increase production output, but to ensure than any increases can be delivered in a sustainable way (taking into account economic, environmental, and social dimensions of production).

The aquaculture industry faces a number of technology trajectories, which includes the option to commercially produce Genetically Modified (GM) fish[2] and it is claimed that if developed sustainably, this GM technology could contribute to increased food security. However, the potential use of GM technology raises a number of important ethical questions. By applying an ethical framework, this paper represents a first (descriptive) phase characterization of key ethical issues raised by the potential use of GM technologies in aquaculture as a significant technological trajectory for the industry. Hallerman (1997) and Kaiser (1997) have highlighted a number of the emerging ethical issues. This paper will hopefully extend this earlier discussion by applying a framework-based ethical analysis to explore a number of issues raised, in particular highlighting some of the issues raised for aquaculture development. Before examining the potential ethical

[2] Refer to Beardmore and Porter (2003) or Maclean (2003) for technical information regarding the production of GM Fish.

impacts, both positive and negative, that may result from commercial use of GM fish, it is valuable to highlight the production trends within the industry.

2. AQUACULTURE PRODUCTION TRENDS

Modern aquaculture is truly an industrialized food process. Advances in the development and application of technologies in the industry have had a significant impact on production, exemplified by the extent to which output has increased over the last twenty years, both in the developing and the developed world. In terms of overall aquaculture production, China is the major producer, followed by India, Indonesia, and Japan (FAO, 2004b). China is now the single largest aquaculture produce exporter, accounting for 71% of the overall market (FAO, 2004b). This export success is largely attributed to its recent improvements in production efficiency and the size of enterprise involved in export production. Although there are a number of specialist export markets, for many other Asian aquaculture producing nations, much of the finfish produced is reserved for internal markets and local consumption, playing an important role in national food security, such as for Indonesia, Vietnam, etc.

In terms of specific innovations, uptake of production technologies such as improved containment systems, nutrition, improved spawning, and selective breeding, have played an important role in improving production. Even though production efficiency has increased, the industry still faces other challenges in areas such as resource use, waste management, infrastructure investment, and product quality/traceability. Technological developments have improved both production efficiency and the quality of fish products produced in aquaculture systems. Although important scientific advances have been achieved over the past few decades, some of the most significant problems that face the aquaculture sector globally are unlikely to be solved through technical innovation. Issues of adequate inward investment, improving overall production efficiency, waste management, and increasing the availability of sustainable resources are a few of the key management challenges (Muir, 2005; Subasinghe, 2003). These are important aspects to consider when reviewing the overall objectives of the technological trajectories proposed for the aquaculture industry.

Aquaculture plays a fundamental role in local communities in many countries and this analysis highlights the importance of considering social and cultural impacts of potential technology trajectories, as well as the consideration of increased productivity. Future advances in the industry need to ensure the development of sustainable aquaculture production systems that protect the environment, maintain product quality, and enhance producer autonomy through access to markets, as well as respecting local cultures. These are important dimensions of the social, economic, and environmental role of aquaculture as a global food production enterprise.

3. TECHNOLOGY TRAJECTORIES

Across the whole aquaculture sector, use of a number of genetic enhancement processes are now commonplace, such as the use of hatcheries technology to supply fish farms and enhanced selective breeding. Building on these recent and rapid technological advances, for many in the scientific and industrial community, the use of GM techniques to further extend current production improvements appears to be the next logical step. Studies have indicated that the use of GM fish in aquaculture will improve productivity by increasing feed conversion ratios and reducing the time needed for a single production cycle for on-shore facilities (e.g., Aerni, 2004; Goos et al., 2001). The development of commercially useful GM fish strains initially focused on increasing growth rate, but efforts have extended to disease-resistance (e.g., Dunham et al., 2002; Mao et al., 2004; Jhingan et al., 2003). Fish losses from infections are a significant problem in aquaculture production worldwide, therefore the development of disease-resistant fish strains is of considerable commercial interest. Other targets of GM research include improved freeze resistance/cold tolerance in extreme environments; better tolerance to pollutants; control of sterility; improved nutritional qualities and food utilization to reduce the requirement for fish-based diets (Hew and Fletcher, 2001; Maclean, 2003). Despite potential productivity gains, a range of key issues are raised (such as those pertaining to ecological impacts, food safety, biodiversity, animal welfare, etc.) that make the proposed use of GM controversial for the industry (NRC, 2002).

Extensive laboratory work has been conducted, to date at least 14 species of fish and shellfish have been genetically modified for increased growth rate including Coho salmon, Atlantic salmon, Rainbow trout, Common carp, Arctic charr, and Tilapia (PIFB, 2003). More novel modification approaches are focusing on use of vegetable products in aquacultural systems, through attempts to alter the carbohydrate metabolism of salmonoids (Maclean, 2003) and phytate utilization (Hostetler et al., 2005). It has been proposed that fish could also be modified to provide more nutritious food products. One example is the genetic modification of rainbow trout to increase the amount of the omega-3 fatty acid that they produce and store (Kok and Jones, 2004). GM techniques are also being developed to provide improved pathogen resistance and to prevent release of modified genes into the environment (Zbikowska, 2003).

As a result of biotechnology innovation in a number of key aquaculture producing countries, such as China, there is growing pressure to move commercial aquaculture production into a new phase by applying genetic modification (GM) technologies. Although current technological developments are focused at present on enhancing production efficiency, as mentioned, future innovations are likely to focus on production areas such as improving the nutritional quality of the product or increasing disease resistance in the modified fish. These new breeds of GM fish have been proposed as a technology option for increasing productivity and production output in a number of developing countries. As well as the commitment made by a number of aquaculture companies, countries such as China, India and Cuba have made "significant" investments in GM technologies through national research programs.

At present, no GM fish have been licensed for use in commercial production. A number of patents have been granted for GM fish, from Devlin et al., (WO9216224) in 1992 through to more recent patents, for example Zhiyuan et al., (2000) for the glowfish and Dunham et al., for (2007) for disease resistance,[3] but only one commercial company, Aqua Bounty, has openly applied for a commercial production license.[4] This is currently under review with the US Food and Drug Administration (FDA), with a decision pending. In terms of EU positions, the European Commission has stated that GM fish have potential to cause irreversible damage to fish stocks and to the marine environment in the event of escape. To date, the Commission has not received any notification with respect to experimental releases of GM fish or any commercial production license applications. Such authorizations may only be granted subject to the provision that there is no reason to believe that the release could have any adverse effect on human health or the environment.

[3] For Example: (1) Devlin et al., (1992) Monsanto Company and Ministry of Fisheries and Oceans, Canada WO9216224 Increasing growth of fish by administering bovine placental lactogen to increased feed conversion efficiency; (2) Zhiyuan et al., (2000) National University of Singapore. WO0049150 Chimeric Gene Constructs For Generation Of Fluorescent Transgenic Ornamental Fish); (3) Dunham et al., (2007) University of Auburn, Alabama, USA US 07183079 Granted 27 Feb 2007. Compositions and methods for enhancing disease resistance in fish Non-food related species.

[4] Under FDA rules (Food, Drug and Cosmetics Act, 1938), license applications are confidential until a decision is reached. Therefore it is highly possible that other licence applications could be pending.

The potential deliberate release of transgenic fish without containment measures raises public concern in terms of risk to the environment. Introduction of new species may also lead to the introduction of diseases, both to farmed and wild stocks................ the Commission is also examining the need for specific legislation on transgenic fish.......... To minimise other potential environmental risks, the Commission will consider the development of rules on containment of farmed fish, the implementation of management rules on the introduction of non-indigenous aquatic species, as well as the need for specific legislation on transgenic fish (CEC, 2002).

It has been claimed that the current US FDA assessment procedure (assessing these biotechnologies through the animal drugs program) has a narrow remit and therefore the licensing assessment may not take adequate account of key environmental, welfare, and societal concerns (Logar and Pollock, 2005).

4. ETHICAL ANALYSIS OF THE USE OF GM FISH

Although a number of ethical issues have been previously raised (e.g., Hallermann, 1997; Kaiser 2005), examining the implications of GM aquaculture development in the broader framework of development is a challenging task. Several prominent issues and questions have been identified. These include the following:

(i) What are the comparative issues raised by using different technologies in aquaculture development in terms of environmental impacts, food security and safety, production efficiency, distributive justice and wider international development implications?
(ii) How might international competition driven by technological change influence current regulatory frameworks and impact on international trade in fish products?
(iii) What is the extent to which key aquaculture producing countries with scientific strengths (e.g., China, India, Cuba) may proceed with developing and applying GM technologies, and what are the potential ethical issues raised by such decisions?

In order to explore some of these issues and other key questions that arise, an ethical framework has been used to map potential impacts. A first phase analysis has been conducted that maps out what is deemed to be the prominent ethical impacts (positive and negative) that may result from the application of GM technology to aquaculture. The analysis also includes the identification of policy implications and areas where further research and ethical discourse is potentially needed.

The ethical framework applied is the Ethical Matrix (Mepham et al., 2006). The method was used to map the issues for the defined interest groups affected by the use of these technologies. The Ethical Matrix (EM) is based on the application of *prima facie* ethical principles that encapsulate traditional ethical theories in the form of a "common morality." The application of the Ethical Matrix facilitates the assessment of biotechnology use in terms of respect (or lack of respect) for three ethical principles – wellbeing, autonomy, and fairness as applied to the defined interest groups. For the analysis of the use of GM in aquaculture systems, four interest groups have been defined (Table 1). The interest groups are defined as Treated Organisms (e.g., fish), Aquaculture Producers (including producers from Developed and Developing Countries and their related communities; commercial producers; technology providers) Consumers (e.g., consumers, affected citizens), and the Environment (e.g., biota, water quality).

The use of GM technology is assessed to determine whether it respects or infringes each principle (i.e., whether there is a positive or negative ethical impact). The weight assigned to particular principles in specific cases is determined by the evaluation and appeals to several forms of evidence. As defined by Mepham et al. (2006) "evidence" is "anything that provides material or information on which a conclusion or proof is based. "For example, forms of evidence included in an ethical analysis are (Mepham et al., 2006):

- Primary scientific and economic data
- Assessments of the value of different forms of life (e.g., different viewpoints relating to concepts such as intrinsic value)
- Risk assessments and notions of uncertainty (e.g., reflecting different interpretations of precaution)

Qualitative or quantitative assessments of impacts as identified in the ethical analysis provide a map of key issues, the different weightings of these determine the nature of the final ethical judgment. This form of analysis facilitates an assessment of the potential technology trajectories for the GM case.

5. IMPACTS ON NAMED INTEREST GROUPS

Using the Ethical Matrix specified for the use of GM in aquaculture, the key ethical dimensions, both potentially positive and negative, are explored for the four interest groups. By their nature, the defined groups represent a broad range of interests, however, the heterogeneous members of these groups hold some shared interests and therefore are discussed under the single headings, e.g., Aquaculture Producers. The analysis highlights a

Table 1. Translation of the matrix for GM use in aquaculture.

Ethical matrix (Translation of the principles for the corresponding interest groups)

	Wellbeing	Autonomy	Fairness
Treated organism (fish)	Animal welfare	Behavioral freedom	Intrinsic value
Aquaculture producers (local and national)	Satisfactory income, and working conditions	Managerial freedom	Equitable IPR conditions, trading and market systems
Consumers (including affected citizens)	Food safety and quality of life	Informed democratic choice	Equitable access to food
Environment (biota)	Protection and conservation	Biodiversity	Sustainability

number of specific dimensions, in particular focusing on the areas that have relevance to the potential use of GM fish in aquaculture development.

5.1. *Treated Fish*

The first generation of growth enhanced GM fish show no potential to respect the ethical principles as applied to the treated fish. Several studies directly or indirectly record welfare issues for the treated GM fish, particularly in relation to Growth Hormone (GH) GM fish (Hallerman et al., 2007; Beardmore and Porter, 2003). With increasing knowledge of fish welfare and pain perception studies for a number of fish species and the growing significance of these issues for both regulators and the industry, the implications of genetic modification on fish welfare is an increasingly important dimension of the assessment of these technologies. In addition to the negative impacts on welfare already recorded, there are also a number of welfare questions relating to these modifications and the production methods, such as the impacts of the containment methods on fish behavior, that remain unanswered. It has been suggested that modified production systems may to some degree counterbalance any behavioral changes (Hallerman et al., 2007), however the risks associated with this form of balancing are unclear. This type of production system modification may also be problematic for a number of producers in developing countries. These issues need further investigation and consideration before a judgment can be made on the extent to which the commercial production of first generation GM fish will infringe the principle of wellbeing and autonomy.

5.2. *Aquaculture Producers*

When examining the role of this new group of technologies in aquaculture and the potential ethical impacts in terms of development, mapping the impacts for aquaculture producers, particularly from the Least Developed Countries (LDCs), is paramount.

When examining key objectives in aquaculture development, one of the main challenges is to ensure that the industry continues to grow at its current pace so that it can provide much needed food security, but that it achieves this in a sustainable manner. In particular, it is important to ensure that important economic gains from these enterprises for rural and urban communities, as well as regions, are not offset by extensive environmental and social costs. Support mechanisms needed to underpin sustainable aquaculture development have been characterized as improved access to: (i) good practice training; (ii) current production technologies, and (iii) product markets (Muir, 2005). As a result, general improvements in the overall standards applied to aquaculture production may be needed before more complex technologies can be applied successfully. Considering the improvements, both in terms of physical infrastructure and institutional reforms needed to support current technology transfer (such as improvements in engineering systems and disease management), the use of GM fish even in the medium-term would appear unlikely to respect the principles of fairness and autonomy for the vast majority of aquaculture producers. It has been suggested that technology and knowledge transfer programs that support improvements in resource management and the uptake of existing technologies, are needed before GM technologies could be considered for widespread use in developing countries.

In terms of producers' autonomy and technology access, and as highlighted by Hallerman and Kapuscinski (1990), if GM fish were to be licensed, the use of the technology is likely to benefit large commercial producers who would see production gains and increased profitability. For small producers there is a large degree of uncertainty over how these modified fish would fare in low input systems. Dependence on biotechnological companies for the "seed technology," mostly in the form of commercial fish fry might also result in commercial monopolies that would limit the choices and viability of small producers. Intellectual Property Rights (IPR) that restrict farmers' ability to "reuse" or develop products, will infringe the principle of autonomy, and also the principle of justice as fairness, if applied to the use of these technologies. Large producers may also have the ability to externalize some of the production costs (Pretty et al., 2000), creating secondary impacts and again potentially undermining more sustainable low-input systems.

When considering producer wellbeing and fair access to markets in developing countries, there is limited analysis of the impact of the use of these forms of technology on small producers and their local communities (Hallerman and Kapuscinski, 1990). Extensive use of this technology by large producers may undermine market access for small producers, limiting their access to much needed incomes, and so widening the poverty gap. It is also unclear how the use of this technology may impact on balance of power of local producers. Economic and social impact assessments of production scenarios at a local level are needed, in order to ensure that local development opportunities are not undermined by the introduction of these technologies.

The IPR conditions affecting use of the technology and the possible market restrictions raise key issues of distributive justice for producers in developing countries and further analysis is required. Recent reports analyzing the role of innovation and IPR in public health provision for developing countries, highlight the need to consider these issues comprehensively so that the most in need of technological support and innovation are not further excluded (WHO, 2006).

Many international bodies have preliminarily reviewed research outputs related to the use of GM fish. However, there is a need to bring together national regulators, producers, researchers, user representatives and a number of international organizations, potentially through a stakeholder engagement forum, to develop good practice guidelines, to discuss key issues, and review approaches to acceptable risk management. These discussions should be linked to a strategic discussion of technology use in development. The empowerment of local users enabling them to participate in these discussions is an important, if not an essential dimension of this strategic dialogue.

5.3. *Consumers*

As with the regulatory discourse for previously assessed GM foods, studies to date indicate that there are limited food safety issues raised by GM fish consumption (Kok and Jones, 2004). However, no specific toxicity tests have been conducted on GM fish products and concerns have been expressed regarding the concept of "substantial equivalence," which is officially recognized as a criterion of safety for the assessment of novel foods. Even if not flawed for all cases, this concept may have significant limitations for the GM fish case. It has been proposed that in order to reduce risks of allergenicity, any GM fish produced should use techniques that do not introduce avoidable consumption risks (e.g., the inclusion of DNA of viral origin, reporter genes, or other genes not required for the target phenotype) (Maclean, 2003). As has been proposed for all novel food products, extensive food safety testing should be carried out for all GM fish products to ensure that the principle of wellbeing is respected.

For GM food products, the food safety risks that consumers are willing to accept are modulated by the perceived need for the technology and how "problem-oriented" the application of the technology. Consumer aversion to the use of GM crops, particularly within the EU, is likely to be repeated for GM fish products. As well as the modulation of acceptable risk, the cultural framing of fish as a food component in many regions in Europe and Asia may also amplify consumer aversion to GM fish products. If realized, this will impact on product markets and significantly undermine the viability of GM in aquaculture production for high value export markets. The perception of GM foods within many developing countries is poorly understood, but as demonstrated by Pimbert and Wakeford (2002) the acceptability of GM use in developing markets should not be overestimated. More information is required on consumer purchase preferences both for developed and developing markets and the values that underpin these positions.

Clear labeling policies for all fish products would need to be further developed and appropriately introduced if GM technologies were used. In the

EU, regulators have explored this issue under the novel food regulations, but further work is needed and this should be carried out in consultation with consumers, producers, and retailers to ensure clear and informative labeling, hence respecting consumer autonomy. National and regional labeling policies will have global implications for the management of the production chain. It is likely that a number of food producers will opt for voluntary "GM free" labeling schemes (as currently pledged) and this may further complicate the labeling process. Users of fish by-products will need to incorporate any labeling and sourcing strategies into their current processes. The logistical implications and the impact of these changes on aquaculture producers from LDCs who are supplying emerging markets, represent a considerable concern, particularly in terms of establishing fair trading systems. The issue of labeling requires further review and evaluation.

5.4. *Environment*

The potential ecological risks posed by GM fish have been widely discussed and characterized as significant by a large number of institutions and regulators (NRC, 2004, 2002; PIFB, 2003). The production option to use sterile (e.g., triploid) fish may mitigate a number of potential negative impacts related to intraspecific and interspecific interactions, but even this form of modification is not without environmental risks.

As well as the significant ecological issues raised by potential escapees, there appears to be limited assessment of the specific production conditions that would be required for commercial GM fish production. There is a need to characterize the environmental impacts of any changes in production methods that may result from the use of GM fish, particularly in relation to pollution, energy, and land use. Confinement conditions and welfare implications have been discussed (ABRAC, 1995; Hallerman et al., 2007 respectively), however a predictive environmental impact assessment (EIA) for specific production conditions is likely to be informative when considering the ecological implications. There is also a need to assess whether these technologies will deliver production levels predicted in laboratory studies and how specific modifications (i.e., for disease resistance) developed for low input sustainable aquaculture systems will fare commercially.

6. MAPPING THE ETHICAL IMPLICATIONS OF POTENTIAL TECHNOLOGICAL TRAJECTORIES

The global market has already shown resistance to the use of GM technologies in food production and initial analysis indicates that this resistance will be extended and possibly amplified if GM fish and shellfish were licensed for use in aquaculture production. The present cultural symbology of fish will modulate the acceptability of any GM products and this is also likely to be a significant factor. Within the premier market sector a number of fish farming companies (e.g., the Canadian Aquaculture Industry Alliance; Interior Alaska Fish Processors Inc.) have issued statements indicating that they will not use GM technology directly or source GM fish products (Center for Food Safety, 2002).

Market resistance and the number of regulatory and trade uncertainties (e.g., as observed with WTO rules relating to other GM food products) surrounding the use of GM fish, is likely to impact on the potential uptake of this technology within the fish industry in Europe and, possibly to a lesser extent, in North America. For those sectors of the industry in developing countries that are focused on export markets as well as increasing production for local markets, economic uncertainties and potential retailer aversion to GM products are likely to act as a barrier to GM use.

There are also a number of issues raised by the use of GM technology in aquaculture that need further analysis and consideration. These ethical issues will affect the regulatory process, but they also need to be further considered beyond market conditions, as important issues for development of the industry, particularly in relation to the proposed use of these technologies in developing countries. The use of GM fish raises a number of welfare concerns that require further assessment (Hallerman et al., 2007). The potential increases in productivity from the use of GM fish with accelerated growth, could make significant contributions to local access to high quality protein in a number of developing countries. However, there are concerns that respect for justice for producers in developing countries will not be evident, particularly in terms of economic access to the technology and the IPR conditions that will apply to the technology.

Further development of GM aquaculture, focusing on disease resistance and reduced external inputs, might be more acceptable to all parties (e.g., producers, regulators, and consumers) than current growth enhancement models. However stakeholders' perspectives of ethical acceptability will not only be modulated by distribution of risks and benefits, but also by the impacts on stakeholder autonomy and notions of fairness. There is need to stimulate an informed dialogue between all affected stakeholders to further explore the perceived opportunities for the aquaculture industry and the ethical issues raised by various options. As part of this process, which could be structured using an ethical engagement framework and mediated by an international institution such as the FAO, strenuous efforts should be made to ensure the participation of producers and their representatives from developing nations.

Although a number of international organizations and commercial companies have predicted that the approval of applications to use GM fish commercially is imminent, current technology impact assessments appear to indicate that there are still a number of regulatory barriers to overcome. Even if licensed, it appears somewhat premature to predict that GM fish will play a significant role in global aquaculture production in the near future. However, two factors, the speed at which the technology has advanced in South Asia and the US regulatory review of the Aqua Bounty application (AquaAdvantage™), will undoubtedly strongly influence individual national and international regulations and uptake of the technology.

The use of GM aquaculture technologies may have the potential to contribute to increased food security, particularly in LDCs. However, although laboratory tests and production trials have indicated the potential for positive ethical outcomes through improvements in production efficiency, resulting from increased growth and maturation rates, the preliminary analysis has identified a number of potential environmental risks and social equity concerns. These potential impacts need to be considered in any regulatory assessment. These ethical impacts affect the claims that widespread use of GM technologies in aquaculture production represents sustainable production methods, particularly when considered in the context of wider development goals.

There is concern that the boundaries set by the USA FDA for the current regulatory assessment of the first GM application for aquaculture, the Aqua Bounty application, are not broad enough to include a full analysis of the potential ethical issues raised (Logar and Pollock 2005). Although there is notable debate surrounding appropriate framing of the assessment, a number of the prominent ethical concerns, in terms of environmental and social impacts, may not be adequately considered as part of this regulatory process. As also noted by Logar and Pollock (2005), if licensed in the US, this ruling may initiate a technological treadmill cycle that, within the current WTO mediated global economic arena, will dominate the conditions under which the technology will be applied and regulated globally. In addition, the potential impacts of GM technology in aquaculture for developing countries, have received limited attention to date and require more structured analysis. Although this review of the use of GM technology is a preliminary assessment of the ethical impacts, the analysis has characterized a number of issues raised by the potential application of this technology. A comprehensive analysis of the technology development trajectories, in terms of international policy, IPR, and operational implications, as well as an analysis of a broader range of ethical concerns, is needed.

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