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ARTICLES

Ethical Issues in Aquaculture Production

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Abstract The ethical issues raised by aquaculture were analyzed. A modification of the Ethical Matrix of the Food Ethics Council for the evaluation of novel foods was used; the Ethical Matrix was changed in order to include the various aquaculture production stages separately. The following stages were distinguished: the breeding stage, the growth/feeding stage, the "other-handling" stage (that includes disease and treatment, transportation of organisms, killing procedure, and DNA vaccinations), and the commercialization stage. The ethical issues concerning the producers, the consumers, the environment, and the aquacultured organisms, are discussed. This scheme was fitted to the intensive cage-culture of carnivorous fish. The differences with other forms of aquaculture are discussed, and how the scheme extrapolates to them. The ethical evaluation of aquaculture, in practice, will be rather a utilitarian balancing of cost and benefits of the respective actions. The desired characteristics of an ethical evaluation have been also outlined. Ethical evaluation should not be limited to a purely scientific analysis; it should be holistic, comparable to available alternatives, and should have the flexibility to incorporate new data generated in the fast growing/continuous changing aquaculture sector.

Keywords Ethics · Ethical Matrix · Seafood · Fish · Aquaculture · Sustainability

Introduction

Modern aquaculture encompasses all activities associated with rearing of aquatic organisms. According to Naylor et al. (2000), the two key criteria for distinguishing

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aquaculture from capture fisheries are the ownership of the stock and the deliberate human intervention in the production cycle.

Diversification of cultured species is one of the basic characteristics of contemporary aquaculture. More than 240 species, from 94 families (this includes 146 fish, 53 mollusks, 30 crustaceans, and 9 plant species) are currently produced in a variety of production systems such as ponds, tanks, raceways, and cages (Tacon 2004; Food and Agriculture Organization of the United Nations, Rome (FAO) 2007). Intervention in the aquatic organisms' life cycles range from the simple exclusion of predators and control of ecological competition (extensive aquaculture), to natural food enhancement (semi-intensive aquaculture), and to the provision of all nutritional requirements (intensive aquaculture) (Naylor et al. 2000).

Aquaculture contribution to global supplies of aquatic products has increased from 3.9% of total world fisheries production in the 1970s, to more than 32.4% nowadays (Food and Agriculture Organization of the United Nations, Rome (FAO) 2007). Almost half of the total aquaculture production is derived from finfish, while the remaining is covered by the farming of mollusks, crustaceans, and plants (Food and Agriculture Organization of the United Nations, Rome (FAO) 2007). Freshwater aquaculture dominates in terms of production quantities (56.6% according to Food and Agriculture Organization of the United Nations, Rome (FAO) (2007)). Most of the global aquaculture output is produced by the developing countries, and therefore in low-income and food-deficit countries (Food and Agriculture Organization of the United Nations (FAO) 1997, 2007).

The increase in fish per capita consumption for almost 5 times from the 1960s, and the respective global population growth, have led to world consumption of food fish more than tripling over the same period (Brugére and Lidler 2004).

Most capture fisheries have approximated their limit and their past decade production has remained relatively stable with El Niño-driven marked fluctuations (Food and Agriculture Organization of the United Nations, Rome (FAO) 2007). Even if their output continues to grow, they will be incapable of meeting the projected demand for food fish according to the global forecasts for food fish demand (Brugére and Lidler 2004). There are also some pessimistic predictions of global collapse of all currently fished species by 2048 if current yields maintain (Worm et al. 2006). On the other hand, aquaculture production has greatly outpaced the human population growth rate and continues to grow more rapidly than all other animal food-producing sectors (Food and Agriculture Organization of the United Nations, Rome (FAO) 2007), and thus aquaculture has been also referred to as the "blue revolution." The latter analysis, allows us to understand the necessity of aquaculture existence to support the global human needs for protein.

Aquaculture, like all agricultural and food production processes, raises numerous ethical dilemmas. This has been well understood by the involved parties and depicted in the general guidelines that have been established by stakeholders, like, for instance, the Federation of European Aquaculture Producers (FEAP) code of conduct (www.feap.info), the Holmenkollen Guidelines for sustainable aquaculture (http://www.ntva.no/rapport/aqua.htm), and FAO technical guidelines for responsible fisheries (Food and Agriculture Organization of the United Nations (FAO) 1997, 2007).

Ethical concerns about aquaculture have increased lately together with the general food issues, like the genetically modified (GM) food debate, incidences concerning food safety, societal acceptability of multifunctional food, the responsibility and accountability of the food producers with regard to obesity, animal welfare, a growing lack of food security for people, etc. (Deblonde et al. 2007). Another fact that may have led to the increase of interest about aquaculture ethics, as well as to the enhancement of pressure for solving the ethical problems that derive, is the rapid growth of aquaculture during the most recent years, as mentioned before.

Agricultural ethics in general, have been a subject of contemporary research (Marie 2006; Thompson 2008; Thompson and Hannah 2009; Ilea 2009). Some specific ethical aspects in aquaculture, have been drawn special attention. These mainly include fish welfare (Huningford et al. 2006; Cotee and Petersan 2009) and sustainability of aquaculture (Frankic and Hershner 2003; Focardi et al. 2005; Tacon and Metian 2008), while some environmental, toxicological and health issues of aquaculture have been recently reviewed (Cole et al. 2009). Some studies also occur in other specific aspects of aquaculture ethics (Kaiser 2000, 2002).

The aim of this study was to make an overview of the ethical issues that are practically related to the aquaculture procedures. The extensive review of the existing literature, referring to each of these specific ethical issues, is not within the ambition of this study. The vast amount of existing data would not allow this in a single journal publication analysis. In the following, we will examine the evaluation characteristics required towards ethically accepted solutions; the use of examples of aquaculture-derived ethical dilemmas will facilitate this effort.

Methodology for Examination of Aquaculture-Related Ethical Issues

For systematic evaluation of current ethical issues regarding aquaculture, we propose the use of the Food Ethics Council scheme (Food Ethics Council 1999), as modified by Mepham (2000).

This scheme includes the three involved groups in a food production process, i.e., the producers, the consumers, and the environment. In case of animal food production it also involves a fourth group, the treated organism.

The same scheme also encompasses the ethical principles that, according to the former, outline the common-sense ethics. The Food Ethics Council (1999) has concluded with three major ethical principles.

The principle of autonomy (i.e., our duty to respect everyone/everything) philosophically derives from the deontological theory of Immanuel Kant. According to the latter, the decision of what is ethical is based in our duties without calculating the consequences, and our major duty is to "treat others as ends in themselves."

The principles of beneficence (i.e., doing good) and nonmaleficence (i.e., avoid producing harm) have been combined for simplicity in the principle of wellbeing. The ethical principle of wellbeing corresponds to the utilitarian theory of Jeremy Bentham and John Stuard Mill. According to it, what is ethical is concluded after weighing the costs and benefits and finding the positive balance among them, i.e., the ethical is what produces the greatest possible good.

Justice (i.e., something ethical implies that no favoritism will be shown), can be interpreted as the common sense of fairness. The ethical theory that corresponds to justice as key-principle is that of John Rawls (1971). He was concerned to develop a principle that would allow one to decide how to distribute resources in a society. According to Rawls, the *veil of ignorance* among people, i.e., not knowing how various alternative acts will affect their own particular cases, allows no one to tailor principles to his advantage.

The interaction of the involved interest groups and the ethical principles gives the ethical impacts that have been presented in a form of a table by the Food Ethics Council. This scheme, also known as the “Ethical Matrix,” has been developed for the evaluation of novel foods (Table 1).

Explicatively for the former scheme, in environmental aspects, any act that directly destroys the biota, e.g., kills organisms or destroys their habitants, is considered a violation of environmental wellbeing; any impact to biodiversity is considered as change of environmental autonomy, while any unsustainable use of the resources consists of a violation of justice.

A question that the former analysis generates is whether, and at what degree, the ethical theories oppose each other and whether they can be considered in one scheme. Such an analysis has been previously taken place (Thompson 2001; Grigorakis 2006) and is not within the present aims of the study.

Also, the ability of actual ethical evaluation through the Ethical Matrix has not been without criticism. Fraser (2001) made a three-point criticism claiming that the ethics application has gone through hyper-commoditization, hyper-rationalization, and hyper-simplification. According to Korthals (2002) the matrix remains a narrow approach, since no analysis of principles and norms is sufficient for a synthesis or construction of ethical solutions.

The value, however, of the Ethical Matrix as an instrument for practical examination of the arising ethical issues in certain human activities, is beyond doubt (Kaiser and Forsberg 2001; Grigorakis 2006). Among others, the Ethical Matrix has been recently used for ethically assessing fisheries (Kaiser and Forsberg 2001) and for ethical evaluation of GM Fish production (Kaiser et al. 2007).

An analysis of the separate examination of each aquaculture production stage is proposed in what follows, in order to cover all the ethical dilemmas systematically.

Table 1 The matrix of ethical evaluation of novel foods, as developed by the Food Ethics Council (1999), as modified by Mepham (2000). (Source: Grigorakis, 2006)

	Wellbeing	Autonomy	Justice
Environment	Conservation of the biota (protection of the environment)	Biodiversity maintenance	Sustainability of biotic populations
Producers	Adequate income and working conditions	Freedom to adopt and not to adopt	Fairness in trade and law
Consumers	Food safety and acceptability	Choice of food	Universal affordability of food
Treated organism	Welfare issues	Behavioral freedom	Telos

The following stages in the aquaculture production can be distinguished: breeding-reproduction, growth/feeding, other handling (therapeutic, transportation, and killing processes), and processing/commercialization of end product. The aforementioned stages mainly refer to intensive fish culture, but any aquaculture activity comprises one or more of these stages.

A separate issue is the genetic modification in the aquaculture; this includes both GM-fish production and the use of genetically modified raw materials in the feed production. The ethical dilemmas related to genetic modification in aquaculture are the same as those for any other genetically modified food and have been sufficiently covered in the literature (Myhr and Dalmo 2005; Millar and Tomkins 2007; Cole et al. 2009).

Within these frames, the proposed scheme is based on the classical Ethical Matrix, but differentiated by the separate aquaculture production stages examination, in order to achieve a complete and specified approach (Table 2).

Current Ethical Issues in Aquaculture

Since growth of aquaculture is an inevitable need in order to support human populations' protein and essential fatty acids global requirements, as derives from the introduction analysis, we may reasonably conclude that any intrinsic objections about the aquaculture activity itself (i.e., someone's view that aquaculture as process is unethical per se), has no strong grounds. Therefore, any ethical arguments objecting to aquaculture extrinsically can be found by the aforementioned methodology.

The respective ethical issues have been summarized in Table 2.

Breeding

In the stage of breeding, the major ethical issues lie within the ethical principle of the autonomy of environment and of fish. In environmental aspects, the biodiversity maintenance is questioned when selective breeding occurs for the organisms. The environmental autonomy is violated by the selective breeding of a species over other organisms that are ecologically implicated (i.e., they use the same resources or are involved in the general food chain with the selected species). Historically, past experience with the effects selective breeding in salmon biodiversity is an example supporting these (Naylor et al. 2005; Einum et al. 2008; Wood and Gross 2008). Of course, to what extent the biodiversity, hence the environmental autonomy, is affected is to be answered depending on the case.

A major ethical question is whether the enhancement of spawning with artificial methods consists of a violation of the organism's autonomy, and to what degree this happens. For instance, beyond natural gonad maturation, there are methods of milder (maturation through artificial photoperiod) or more aggressive (hormonal injections) intervention to the gonad maturation process (Donaldson 1996). A violation of organism autonomy is more likely to occur in cases of direct intervention in gonadal maturation, but the question is difficult to be answered when

Table 2 Ethical issues of aquaculture

	Producers	Consumers	Environment	Organism
Breeding			Biodiversity maintenance (*autonomy*)	A. Behavioral freedom in reproduction (*autonomy*). B. Animal welfare: aggressive techniques for gonad maturation (*wellbeing*)
Growth/feeding	Safe working conditions (*wellbeing*)	Nutritional value and safety of produced organism (*wellbeing*)	Pollution by feed and cultured animal excretions (*wellbeing*). Use of environmental resources—environmental sustainability (*wellbeing/justice*) Natural habitats modifications (*autonomy*) Feeding of alien aquacultured organisms from the environment (*autonomy*) Escape of cultured animals (*wellbeing/autonomy*) Aquaculture-mediated species invasions (*wellbeing/autonomy*) New niches for pathogens (*autonomy*). Impacts on natural predators (*autonomy/wellbeing*)	A. Animal welfare: 1. stocking density. 2. quantity of feeding and nutritional demands 3. diseases 4. enhanced exposure to predators. 5. Other human activities (*wellbeing*) B. Behavioral freedom (*autonomy*)
Other handling				
Disease/therapeutic procedures	Safety of processes for personnel (*wellbeing*)	Consumer's safety: 1. Therapeutic agents withdrawal times. 2. aquaculture-derived microbes 3. resistance transfer (*wellbeing*)	A. Conservation of the biota: 1. transmittance of diseases 2. pollution by chemotherapeutics (*wellbeing*). B. Generation of antibiotic resistant strains of pathogens (*autonomy*).	Proper prophylactic measures and therapeutic treatment (*wellbeing*)

Table 2 continued

	Producers	Consumers	Environment	Organism
Transportation			Transportation of invasive species (*wellbeing/autonomy*)	Animal welfare during transportation (*wellbeing*)
Killing	Personnel safety during killing procedures (*wellbeing*)	Effect of killing on the end product quality (*wellbeing*)		Animal welfare: humane killing method (*wellbeing*)
DNA vaccinations		Consumption of vaccinated fish: immune response and other negative results (*wellbeing*)	Genetic change in microbial and viral population (*autonomy*	A. Genetic change in fish population (*autonomy*) B. Immune response (*wellbeing*)
Processing/ commercializing	Fairness in trade (*justice*)	A. 1. Safety and acceptability of end product. 2. Effect of end product in public health (*wellbeing*). B. Choice: traceability issues for aquaculture organisms (*autonomy*) C. Adequacy and affordability of food (*justice*)	A. 1. Handling/disposal of industrial waste: Environmental pollution 2. disease transmission to the wild populations from products for human consumption (*wellbeing*) B. Social impact of aquaculture	

In parenthesis written in italics appears the ethical principle which is the basis of the specific issue each time milder techniques are applied, like photoperiod regulation. Aggressive techniques of gonad maturation also raise welfare issues and appear to have a negative effect to the animal wellbeing.

Growth/Feeding

In the stage of growth, the wellbeing of the producers is related to the safety of the production methods. Occupational hazards in aquaculture have been analytically reviewed elsewhere (Cole et al. 2009) and are categorized into physical work hazards, chemical exposure, and toxic hazards. The chemical hazards have to do with the fact that farmers and workers routinely come into contact with chemicals like antibacterials, disinfectants, antifouling agents, and in many cases are unaware of potential health risks associated with these exposures. Sapkota et al. (2008) have recently reviewed the potential risks associated with antibiotics exposure in aquaculture, and concluded that further research is required to determine the adverse health effects associated with chronic exposures of low-level antibiotic residues. Among these potential health impacts, the balance of microbial communities in the gut and the development of resistance are what seem to be the more profound ones.

The wellbeing of the consumers is questioned in relation to the feeding effects on the nutritional value and safety of the aquacultured organism. In general, the marine organisms, and most of all fish, are considered very beneficial food due to their high contents in $\omega 3$ polyunsaturated fatty acids (PUFAs). It is well known that the nutritional value of the organism is strongly related to its feeding; particularly the fish exhibit fatty acids in their edible part that directly mirror their dietary fatty acids (Fauconneau and Laroche 1996; Lie 2001; Grigorakis 2007; Morkore et al. 2007). Therefore, it is important that the feeds provided and the feeding techniques followed, are those that ensure that the nutritional value obtained is at least equivalent to what the consumer expects from a fish.

In respect to the safety of the produced organism, one would expect that aquaculture positively affects the consumer's wellbeing, since the controlled conditions of intensive aquaculture and the feeds presumably allow a better monitoring in organism life cycle and minimization of safety dangers in relation to capture fisheries. However, surprisingly, some contaminants (polyaromatic hydrocarbons, organophosphates, polybrominated diphenyl ethers, polychlorinated biphenyls) seem to be more abundant in cultured fish (Cole et al. 2009). The most possible explanation for this is that these contaminants originate from the feeds' raw materials, especially fish meals and oils, and are biomagnified (Dórea 2009). Technically, there are solutions proposed to the problem, like the more extensive use of plant raw materials as substitutes (Bell et al. 2005; Friesen et al. 2008; Tocher 2009), the decontamination processes of contaminated raw materials, and the establishment of regulations limiting the consumption of certain fish and for certain consumer groups (pregnant women, children) (Cole et al. 2009). The ethical question that arises is what the impact is of each of these proposed solutions to the wellbeing of the involved parties.

One major ethical concern about environmental wellbeing is pollution caused by the dumping of organic matter resulting from fish metabolism (feces, excretion, and mucus) and feed losses (uneaten feed). Also aquaculture wastewaters may contain inorganic material, planktonic biota, and also various chemicals used in aquaculture or their residues (Tacon and Forster 2003).

The outcome is changes to the physical, chemical, and the biological characteristics of the receiving environment, and mostly on the seabed. The magnitude of the effects depends mostly on the intensity of the production, and the environmental characteristics (i.e., dispersion ability of the currents, environmental carrying capacity to assimilate organic content), but also on the production methodology followed. Another source of aquaculture-derived environmental pollution within this stage is from the antifouling agents, mostly copper levels elevation and the toxic consequences in the aquatic environment.

Within environmental wellbeing and justice, another ethical issue is the extensive and unsustainable use of the environmental resources. The manufacture of feeds in intensive and semi-intensive productions is mainly based upon fishmeals and fish oils, which, however, are not renewable resources. The problem caused to the world fisheries supplies due to aquaculture has been outlined (Naylor et al. 2000; Tacon and Metian 2008). During the recent years, there is a turn towards terrestrial raw materials to substitute for the fish oils and meals at the greatest potential degree and to achieve sustainability in the aquaculture process (Watanabe 2002); and also an attempt to achieve a more targeted usage of fish oils and meals (Tacon and Metian 2008). These attitude changes can only hypothetically be attributed to ethical environmental concerns. The market response to the continuous fish meal and fish oil costs increase and to the structural historical change in the soybean meal/fish meal relationship that occurred in the late 1990s, seems rather to be responsible for this turn (Kristofersson and Anderson 2006; Tacon and Metian 2008).

The potential violation of the autonomy of the environment is an issue that is related to the following aspects of aquaculture—environment interaction; the natural habitat alterations due to the aquaculture occurrence, the escapes of alien cultured fish from captivity and their subsequent interactions with the surrounding ecosystem, the generation of new ecological niches for pathogens due to aquaculture, and the aquaculture impacts on natural predators.

Natural habitat alterations are often a result of either aquaculture constructions (e.g., exclusion of migrating fish passages) or of biological processes of the cultured species (e.g., changing of flow and composition of waters, local extinction of flora and fauna species from feeding) (Cole et al. 2009). On the other hand, aquaculture installations often provide new niches for wild populations of aquatic organisms or seabirds that tend to use them as habitats, and relate their living and their feeding to them (Roycroft et al. 2004; Fernandez-Jover et al. 2009; Žydelis et al. 2009). Although, this may be seen as a positive influence, the environmental autonomy is still changed, since trophic relations, or feeding habits or even nutrition of wild species, are disturbed.

The escape of cultured fish is a usual observation in the practice of cage farming. Interactions of these fish with the local wild populations can have the following results: (1) alteration of natural genetic architecture resulting from transfer of genotypes among differentiated populations used in aquaculture stocks, (2) introduction to wild populations of novel or previously uncommon genotypes, and (3) weakening of native populations of wild fish through the exclusion of native fish by competing escaped aquaculture fish.

The size of the impact on local environment has also to do with the proportion of alien species used for aquaculture, which, for instance, in the case of European inland waters has increased from less than 20% in the 1950s to more than 65% in the recent years (Turchini and De Silva 2008).

The impacts of the introduction of alien aquacultured species in the indigenous flora and fauna (Chapin et al. 2000; Turchini and De Silva 2008), besides disease-related problems, discussed elsewhere in this paper, can be through direct predation or competition, i.e., through reduction in environmental wellbeing, but also through indirect reduction of local biodiversity, i.e., reduction of environmental autonomy.

Besides the introduction of alien aquaculture organisms themselves, invasions of other species, mediated by aquaculture, have been also a threat to environmental wellbeing. These "intruders" are organisms carried by the aquaculture organism or the water, either fouling organisms, parasites, symbiotic organisms, and predators (Galil 2000; Naylor et al. 2001). Numerous examples occur with ecological catastrophic consequences of aquaculture mediated invaders, that have been recently summarized by Molnar et al. (2008).

Within the issues of environmental autonomy, another aspect is the potential generation of new niches for pathogens related to the occurrence of aquaculture units. In general, pathogens redistributions and disease outbreaks have been mentioned to be consequences of high organisms' densities occurring in aquaculture practices (Frankic and Hershner 2003).

The large concentrations of organisms occurring in the intensive aquaculture, or wild fish gathered around farms, attract predators like seals (Güçlüsoy and Savas 2003; Sepúlveda and Oliva 2005), dolphins (Díaz López and Shirai 2007, 2008), and seabirds (Melotti et al. 1993; Roycroft et al. 2004; Žydelis et al. 2009). These predators are often trapped in aquaculture nets or other human construction (Güçlüsoy and Savas 2003; Díaz López and Shirai 2007), or annoyed by the anti-predator measures, or, in some cases, even killed by the farmers. Aquaculture has been proved to affect not only directly the marine predators but also to have indirect influence on their social structure and behavior (Díaz López and Shirai 2008). The predators are indirectly forced to attack the aquaculture installations, due to their inability to find adequate feed as a result of human activities (even aquaculture itself), and directly forced out of their food source due to the anti-predator measures; thus their autonomy is actually reduced by the aquaculture operations. Considering that some of the predators species involved in farm attacks are endangered to extinction, the environmental welfare should be also seriously questioned.

Facing the fact of aquaculture's negative effects on biodiversity, hence environmental autonomy, leads us to the problem we should confront on how we will conserve biodiversity alongside of aquaculture.

On the other side, when considering aquaculture impacts on environmental autonomy and wellbeing, the potential positive impacts of aquaculture on biodiversity conservation should not be neglected. Thus, the reduction of pressure on overexploited wild stocks due to the cultured seafood abundance, the enhancement of wild stocks from stocked organisms, the incidences of natural production and species diversity boosts from aquaculture, and the replacement of more destructive resource uses from aquaculture are the positive impacts that have been pointed out (Diana 2009).

In the growth stage, within the frames of the organism wellbeing and autonomy, there are issues in respect to the stocking densities, the quantity and quality of the feed received by the fish, and its exposure to diseases. The increased stocking densities used in aquaculture are considered to be prolonged stress factors and have been also related to disease vulnerability (Jacobs et al. 2009), while crowding of the animal population has been proved to generate acute stress to fish (Ellis et al. 2002; Huningford et al. 2006). Furthermore fish population density has been related to the bird predation losses (Melotti et al. 1993).

The feeding with industrial feeds generates questions in respect to the organism wellbeing and autonomy. In an ideal situation, the feeds would cover exactly the nutritional needs of the fish, and would be received by the fish when its organism requires it. In practice, it is not only the feed that is adapted to the needs of the organism but also the organism that is adapted to the feed. Actions like weaning prove this; also the fact that different species have different quality as end products when compared to their wild counterparts, also prove that they are not adapted in the same degree to the diets they receive (Grigorakis 2007). Since the aquacultured organism has no alternative other than eating the feed, and this not always at the time and quantity of its choice, its autonomy is violated. Its wellbeing is also questioned when feed fails to fulfill the nutritional needs of the fish. One could argue that the wild fish also don't have the choice of eating (i.e., eating when they want, the food and the quantity they desire), but the counterargument here is that the wild fish has the freedom/opportunity to search and ensure consumption of food covering exactly its nutritional needs; this freedom is absent in aquacultured organisms that feed intensively.

Beyond these, we can also question the organism's wellbeing at the time it suffers enhanced disease exposure and enhanced danger of predation due to the confinement conditions. Other human activities relating to the aquaculture process itself can cause significant wellbeing reduction to the organism. Weighing, grading, net changing, boat passage, and even human presence itself can cause even significant stress to the fish (Braithwaite and McEvoy 2005; van de Nieuwegiessen et al. 2008).

Furthermore, the organisms under aquaculture conditions, in many cases, lack the ability to express their natural behaviors, and thus their autonomy is violated. Characteristic examples are the inability of many of them to breed in captivity, to show natural habitant behaviors, and to defend themselves against predators (e.g., escape, hide).

Disease/Treatment

In the cases of disease and treatment, personnel safety might be questioned in certain ways. There is evidence that some fish pathogens can be contagious to the people working in aquaculture (Durborow 1999). Also treatment itself may put workers safety in danger, due to contact with potential carcinogenic chemical substances (Rigos and Troisi 2005).

Consumers' safety-wellbeing issues refer mainly to aquaculture-derived microbes and biotoxins. Another capital aspect is the occurrence of chemicals used in aquaculture therapeutic processes. The use of antibacterials dictates a withdrawal period to ensure consumer safety, e.g., to allow antibiotics presence to drop below the maximum residue level (MRL) according to the European legislation. However, in a review of the pharmacokinetics of antibacterial agents in aquaculture, Rigos and Troisi (2005) pointed out that withdrawal periods should be determined for each drug, each target species, and at different temperature conditions, in order to ensure that no residues above MRL exist in the edible tissues of farmed products; but respective knowledge provided by research is not sufficient at the present.

Beyond these, the antibacterials use in aquaculture has also been related to the development of resistance for human pathogens (Rigos and Troisi 2005; Sapkota et al. 2008) and therefore to higher vulnerability to potential human disease outbreaks. This transfer of resistance can be directly or indirectly and is also very hazardous to the public health.

The wellbeing of the environment, in cases of disease and treatment has to do with two aspect of the biota conservation; the transmission of microbial pathogens to the wild populations and the pollution from the chemotherapeutics.

Turchini and De Silva (2008) reviewed cases of pathogens that have been introduced to new geographical areas through aquaculture in the inland waters. Transmittance of aquaculture-originated pathogens to wild populations have been proved to be common incidences and even to have devastating effects on wild populations like the cases of viral diseases and sea-lice in salmonids (Krkošek et al. 2007; Rosenberg 2008; Wallace et al. 2008).

Environmental pollution by the chemotherapeutics includes the residues and persistence in the aquatic environment due to uneaten medicated feed, unabsorbed and un-metabolized drug release (Rigos and Troisi 2005). It has been indicated that often antibacterial drugs have not been used with responsibility from the aquaculture industry, that incomplete absorption of the drugs by the treated organism occurs, and that significant quantities of drugs are released into the vicinity of fish farms (Rigos and Troisi 2005; Sapkota et al. 2008). Upon environmental release, drugs can be transferred, make complexes in the water column, accumulate in the sediment and taken up from non target organisms including scavengers and secondary aquacultured species (i.e., wild species that gather around the aquaculture installations) such as crabs, mussels, and certain fish species.

The concentration of aquaculture-derived antibacterials in the sediment can inhibit certain microorganisms that degrade organic matters, while heterotrophic bacteria resistance develops (Ma et al. 2006).

The inhibition of certain microorganisms and the generation of antibiotic resistant strains of microorganisms raise the issue of environmental autonomy violation. Beyond these, the development of antibiotic resistance by bacteria, can lead to increase of diseases and to additional difficulty in effectively treating them.

Furthermore, toxic effects in aquatic organisms have been mentioned from aquaculture-used chemotherapeutics (Jones et al. 2004; Rigos and Troisi 2005) and thus environmental wellbeing is also degraded.

The use of antimicrobial agents in aquaculture is in principle good for the aquaculture organism and enhances its wellbeing. The treated organism's wellbeing, however, is questioned in respect to the right of receiving the proper therapy. The argument that fish in the wild do not receive any treatment can be easily dismissed by the counterargument that fish exposure to disease is magnified due to captivity. Thus, since responsibility occurs for the reduction of their health status, this also creates obligations for prophylactic (e.g., vaccinations, immunostimulants) and therapeutic measures.

On the other hand, treatment itself, in many cases, is a source of stress for the fish (e.g., irritation effects from the used agents). Of course, a logical conclusion is that the wellbeing reduction in this case would be rather negligible compared to that caused by the pathogen, but this in turn, raises the issues of the proper timing and dose of the treatment.

Other Handling

The transportation of organisms for aquaculture purposes, especially among different geographical regions, raises a significant issue of environmental autonomy, since biodiversity can be seriously harmed from the introduction of alien organisms in the environment, as previously mentioned.

Transportation of aquaculture animals raises welfare issues that have to do with stress generated by the existing conditions (i.e., crowding, quality of the water during transportation).

One of the issues that has received special attention is the killing procedure, similar to what happened for most human-food destined animals. In aspects of the producer wellbeing, the safety of the working personnel can be threatened in cases of electro-stunning. Electro-stunning is a method that, in many cases, has been proposed as the more humane/less stressful for the fish (van de Vis et al. 2003). This is widely preferred in cases of freshwater species. However, in cases of marine species, due to the very high conductivity of the water, the application of the high currents required, brings forward the argument of human safety.

Another issue, having to do with consumer wellbeing is the impact of killing procedure to the end-product quality. It has been shown that the killing procedure, beyond others, affects the quality characteristics of the fish (van de Vis et al. 2003; Poli et al. 2005; Knowles et al. 2007).

The major issue, however, is the animal's welfare. In this case, the definition of welfare is the absence of fish suffering during the killing procedure (Huningford et al. 2006). In most ethical theories, sentience of the organism is considered the basic borderline for moral concern, i.e., an animal should be sentient in order to be a subject of welfare consideration (Lund et al. 2007).

A lot of argument has been taking place on whether fish do or don't feel pain or experience suffering. By the term suffering, the conscious experience of something significantly unpleasant is meant. There are contradicting evidences and arguments on one side or another, but none entirely satisfactory. Rose (2002), reviewing the existing literature, concluded that fish lack the essential brain regions or any functional equivalent in cerebral cortex, responsible for experiencing pain or fear. Huningford et al. (2006), on the other side, in their recent review on fish welfare provided evidence that fish have the ability of learning (both associated and more complex), have some types of nociceptors (pain receptors), although quite undeveloped telencephalon (part of brain responsible for pain reception in mammals), and when jawed they produce some of the natural opiates that modulate nociception in mammals. Based on the evidence the former authors concluded that fish have the sense equipment required to perceive harmful stimuli and probably the central nervous system to perceive harmful stimuli that is associated with pain in mammals. One ethical question raised within these, and already pointed out by Lund et al. (2007), is what degree of evidence is necessary in order to admit safe indication of fish sentience.

In most cases, slaughter is a two stage-process (though often the two stages can occur together): the animal is initially stunned to become insensible to pain and then killed. Although Robb and Kestin (2002) summarized the impacts on the welfare and quality of fish of the different existing slaughter methods, it is important to bear in mind that not all fish species respond in the same way in aspects of generated stress during the killing procedures (van de Vis et al. 2003) and that not all techniques are practically applicable for all fish species.

Although the majority of research focuses on the stress created during the killing procedure, the stressful handling, such as crowding, often occurring prior to killing, and having a drastic impact to the fish (Poli et al. 2005; Bagni et al. 2007) is usually overlooked. We should, however, mention that research on adequate methods for fish slaughtering has been prioritized (Lund et al. 2007).

One, of the most recent and innovative technologies followed in aquaculture is the DNA-vaccination, i.e., the vaccines against viral diseases that consist of a bacterial plasmid containing viral genes. Myhr and Dalmo (2005) have reviewed the benefits and risks of this technology. Since DNA-vaccines protect fish against viral diseases, they improve fish welfare and reduce the usage of chemotherapeutic processes.

One ethical aspect is the effect of DNA-vaccinated fish on consumers' health and therefore welfare. No data is available in the literature in respect to any possible effect to the consumer. Little scientific data occur regarding the tissue distribution and degradation of plasmid DNA in the treated organism, which seem to be highly variable with the case and the route of DNA administration (Myhr and Dalmo 2005).

The environment is also ethically implicated, since, due to the lack of physical and physiological barriers in aquatic environments, DNA may be distributed over vast areas, distances, and phyla. Furthermore, DNA has proven more resistant to breakdown than initially thought. Thus, although the prevention of viral spread and the reduction of chemotherapeutics relate to the improvement of environmental welfare, the use of DNA vaccines are questioned in the aspects of the environment's autonomy intervention through the possibility of genetic changes. The treated organism's autonomy and welfare can be both questioned since genetic change and side effects (induction of specific and other immune responses, tolerance) may occur, respectively.

Processing/Commercialization

In the stage of processing and commercialization of fish, what is ethically important for the producers, are issues related to the fairness in trade. These issues are subject of respective research on trade ethics (Renard 2003; Low and Davenport 2009) and their further analysis is not within the scope of this work.

Regarding the consumers' wellbeing, the safety, acceptability, and nutritional value of the product issues are raised. Marine organisms, especially fish, have been rich $\omega 3$ PUFAs sources and have been related to health benefits and particularly in the reduction of cardiovascular disease risk (Kris-Etherton et al. 2002; Galli and Rise 2009). Safety issues in respect to aquaculture products are those aforementioned for the growth/feeding and disease/treatment stages.

It is well established that intensively aquacultured fish differ from the wild counterparts, which, however, does not necessarily correspond to an inferior quality (Cole et al. 2009). In a paper reviewing the literature data on the quality of wild and cultured gilthead sea bream and sea bass for example, it was found that cultured fish for both species contain higher Eicosapentaenoic (EPA) and Docohexaenoic (DHA) polyunsaturated fatty acids contents (Grigorakis 2007). These two essential fatty acids are important for improving human health. However, it is still difficult to be driven into conclusions on whether wild or cultured fish are more beneficial to human health due to the complicated mechanisms involved and the insufficient present scientific knowledge (Grigorakis 2007). The ethical questions that derive instantly are whether, and to what degree cultured fish should be allowed to be something different nutritionally from the wild counterparts; and if so, how is the consumer's wellbeing affected. Under a wider perspective, the impacts of consumption of aquaculture products in the public health are important ethical considerations. The question of how aquaculture affects the public health is difficult to answer. Within these, some recent ethical arguments have been raised. The one big issue is how seafood nutritional-toxicological conflict is balanced (Sioen et al. 2009). Additionally, Jenkins and Josse (2008) have questioned the necessity of fish $\omega 3$ PUFAs, and raised the argument that a human balanced diet can substitute fish $\omega 3$ PUFAs with respective plant and algae fatty acids.

Another ethical issue is the autonomy of the consumer as expressed by its ability to choose his/her food. This is translated to adequate traceability through the production chain and also through sufficient labeling to allow the consumer to receive the information he wants about the food he chooses to consume. Ethical issues about labeling and traceability of food (Grigorakis 2006) and seafood (Jacquet and Pauly 2008), as well as general issues about traceability of seafood (Arvanitoyannis et al. 2005) have been reviewed by the literature.

In aspects of justice, the adequacy and affordability of food seems generally to be positively affected by the aquaculture production. This is due to the increasing quantities of produced fish and to the lower prices than the respective wild caught fish.

Table 3 Indicative forms of aquaculture and their major ethical concerns

Aquaculture forms	Ethical concerns
Algae-culture in non closed systems	1. Issues of ecosystem sustainability (effects on biodiversity)
Mollusk culture	1. Issues of ecosystem sustainability (effects on biodiversity)
	2. Food safety issues (higher than in cultured fish due to the feeding nature of the organisms)
Extensive shrimp-culture	1. Issues of ecosystem sustainability (effects on biodiversity)
	2. Food safety issues
Extensive fish aquaculture	1. Issues of ecosystem sustainability (effects on biodiversity)
	2. Fish welfare (harvesting methods)
	3. Food safety issues
Intensive culture of herbivorous/omnivorous fish* (* the same ethical issues imply for intensive shrimp culture excluding the welfare issues)	1. Environmental pollution (organic, chemotherapeutic
	2. Ecosystem sustainability (all possible organism-environment interactions)
	3. Fish welfare (feeding/growth, disease and harvesting)
	4. Food safety and quality
Intensive culture of carnivorous fish in sea cages (e.g., salmon, tuna, sea bass etc.)	1. Environmental pollution (organic, chemotherapeutic)
	2. Sustainability of feed raw materials
	3. Ecosystem sustainability (all possible organism-environment interactions)
	4. Fish welfare (feeding/growth, disease and harvesting)
	5. Food safety and quality
Hyper-intensive culture of carnivorous fish	1. Sustainability of feed raw materials
	2. Fish welfare (feeding/growth, disease and harvesting)
	3. Food safety and quality

The environmental wellbeing, within the stage of processing can be affected due to the products, the byproducts, and the industrial waste produced during processing. Beyond the obvious effect, the pollution derived from the industrial waste, other less known and less studied consequences appear to exist, like the transmission of diseases to wild populations, derived from products destined for human consumption The transmission of shrimp viral diseases from imported human-food shrimp products is the most studied case, and still very little data are available (Flegel 2009). The ethical dilemmas lie within the proper handling and disposal of wastes and the minimization of their environmental impact.

Another important subject with ethical implications is always the social impact of aquaculture. Within it, we can distinguish between the impacts on local societies and the general impacts regarding the global societies and economies. The socio-cultural and economic assessments have been proposed as important components in evaluating aquaculture development and sustainability, through the available alternatives evaluation, on a cost-benefit basis (Frankic and Hershner 2003).

The above analyzed scheme provides a tool for examining in detail all the ethical issues implicated to aquaculture production.

Discussion

Application of the Scheme

Aquaculture, as mentioned in the introduction, refers to a wide variety of species varying from algae to teleost fish. The trophic levels of these species may also vary from autotrophs to herbivorous, omnivorous, and carnivorous aquatic organisms. The environment at which the production takes place and the breeding methodologies can also be very variable, including open or closed systems with a variable degree of environmental parameters control, extensive or intensive aquaculture, on land, in inland water bodies, in coastal areas, or further offshore.

This automatically implies a quite variable degree of ethical issues raised.

The indicative forms of aquaculture and the ethical issues raised within each one are listed in Table 3.

From the former it becomes obvious that ethical issues increase as we go higher in the trophic level of the cultured organism, as we go to more intensive forms of aquaculture, and as we go to more open-to-environment culture forms.

The proposed scheme that involves all production stages is best fitted for the intensive cage-culture production of carnivorous species, exactly because this aquaculture form raises the highest degree of ethical conflicts. This happens for three main reasons. Firstly, the high trophic level of these species implies that the utilization of plant protein is poorer and the fish biomass required as feed is higher, when compared to herbivorous and omnivorous species (Naylor et al. 2000). Their highest degree of dependance on finite fisheries stocks (Focardi et al. 2005) leads to a maximization of the environmental sustainability disturbance. Additionally, the highest level of human intervention in the organism life cycle generates more ethical implications than the rest, less-intervening aquaculture production systems (Tacon and Forster 2003). Finally, the cage-culture allows maximization of interaction with the surrounding ecosystem due to the lack of any barriers other than the cage net.

However, application of the scheme can take place for any aquacultured organism and any type of rearing system. Of course, the relative ethical issues raised will only partly coincide with the whole analysis. They will, however, be included in this general scheme, even if not all production stages are applicable, or even if not all involved parties are subject to ethical issues. For instance, plant production, including aquatic algae, does not raise any issues about the cultured organism since these apply only for animals (Food Ethics Council 1999). Within the stage of "other handling," only transportation issues imply to any aquacultured organism. Killing aspects and DNA vaccination relate only to the fish culture. On the contrary, consumer's wellbeing, autonomy, and justice issues are involved in all possible aquaculture forms. Environmental wellbeing and autonomy issues are variably raised in all forms of aquaculture.

The previously analyzed scheme actually provides us with any objections that can be raised through aquaculture procedures. In order to achieve an ethical evaluation in aquaculture we have to seriously take into account these ethical objections.

We have to agree with Thompson (1998) that utilitarianism is the most dominant ethical theory in the practice of everyday ethics. Thus, the ethical evaluation of aquaculture, in practice, will be rather a utilitarian balancing of cost and benefits of the respective actions. The major benefits from aquaculture (Frankic and Hershner 2003) for household economies, human nutrition, employment, country economies, preservation of biodiversity (in cases of restocking and recovering of species), fishery resources (in case of aquaculture sustainability), respective research and development, and education and environmental awareness should always be weighed against generated ethical objections.

An ethical evaluation can be about the operation of a certain farm in a specific area, about certain aquaculture procedures (e.g., vaccination), about the ethical application of a custom practice in aquaculture (e.g., is an antibiotic ethically used in aquaculture nowadays?), about certain forms of aquaculture (e.g., intensive salmon culture), about a country aquaculture practices/politics, or for aquaculture as activity, in general, over a geographical region.

We then have to answer what the ethical evaluation should have in order to give ethically accepted solutions.

Examining the Required Characteristics for an Ethical Evaluation

The use of examples from aquaculture practice can be useful in defining the required characteristics of an ethical evaluation. For this purpose, the issue of environmental sustainability with respect to the use of fish oils and meals and the issue of fish welfare with respect to the killing method will be used here as examples.

The rapid development of aquaculture has subsequently demanded an increase in fish feeds. The production of fish feeds mainly depends up to now on fish meals and fish oils. These, however, are mostly non renewable raw materials. Thus, in an attempt to achieve sustainability in aquaculture during the last years, there is a turn towards terrestrial-plant raw materials to substitute fish oils and meals (Watanabe 2002). The use of terrestrial raw materials poses further ethical issues. The produced feeds incorporating these raw materials are distant from what is dictated from the natural feeding. Consequently, there are cases mentioned where reduced nutritional values and feed efficiencies have been observed (Gatlin et al. 2007). Also changes in gut physiology, in immune parameters and even development of pathologies (enteritis) have been mentioned by the use of terrestrial plant raw materials (Baeverfjord and Krogdahl 1996; Sitjà-Bobadilla et al. 2005; Bonaldo et al. 2008; Montero et al. 2008).

In second place, the plant raw materials are not rich in the polyunsaturated fatty acids provided by the marine food chain. The fatty acid profile of the fish mirrors the dietary fatty acids. Although restoration of the polyunsaturated fatty acids is attempted at the end of the production cycle by the use of fish oil-containing finishing diets, this often is not completely achievable, since specific fatty acids are not fully restored (Glencross et al. 2003; Izquierdo et al. 2005; Montero et al. 2005). Furthermore, there are serious indications that there is a negative impact of plant protein use on the organoleptic quality of the fish, i.e., fish having worse texture and flavor (Gatlin et al. 2007). Therefore, there is an issue about the quality and nutritional value of the end product.

On the other side, the use of plant materials secures an advantage, due to the absence of Persistent Organic Pollutants (POP) that are abundant in fish oils (Bell and Tocher 2008).

The use of plant raw materials in fish feeds also brings up for discussion the issue of nutrients (Phosphorus, Nitrogen) transfer. These nutrient transfers destroys the phosphorus and nitrogen cycles in the ecosystem of their production and additionally phosphorus and nitrogen are sources of pollution in the recipient ecosystem. In this case, they are transferred from a terrestrial ecosystem and not simply from one aquatic ecosystem to another, as is the case with fish oils and meals; this can hypothetically lead to a bigger environmental imbalance. On the other side, the comparative evaluation of environmental impact clearly shows that the production of terrestrial plant raw materials and their use in aquaculture have a significant advantage over fish oils and meals, in aspects of the economy of nature (Boyd et al. 2007).

When considering the producers welfare, the substitution of fish oils and meals results to a crisis for their producers, both at the individual fishermen level and at the production countries level; on the other hand, a welfare induction is to be expected for the producers of terrestrial raw materials (profit, job availability increase, etc.)

The evaluation of the available scientific data can give answers on the degree of all of the aforementioned impacts, or even more on how some improvements can be achieved (improvement of the nutritional value of the feeds, or the quality of produced fish, decrease of the side-effects in the physiology of the fish, reduction of the environmental impact). However, scientific data by themselves can not answer issues like, how we rate the reduction of fish welfare, of fish oil and meal producers' welfare, and potentially of consumers' welfare on one side, and the improvement of environmental sustainability on the other side. The former are purely ethical dilemmas and are to be answered with respective terms. Thus, an ethical evaluation is far from being simply a risk analysis or a cost-benefit analysis; on the contrary it requires an ethical component that will give answers, i.e., how we prioritize these ethical entities (fish welfare, consumer welfare, producers' welfare, the environmental sustainability).

The use of plant raw materials in aquaculture feeds should be evaluated not only against fish oils and fish meals but also against other potentially available alternatives (e.g., sustainable sources of fish oils and meals, use of other marine raw materials that are sustainable). Also, we can consider other changes towards reducing fish oil and fish meal, such as reducing some forms of aquaculture in favor of others less demanding in marine raw materials but without significant compromises in the interest parties wellbeing (e.g., selective turn from carnivorous species towards omnivorous).

Furthermore, the turn from the fish oils and meals towards other raw materials, does not guarantee that the sustainability problem will be driven into a solution; at the moment that a fish oil and fish meal demand reduction occurs for aquaculture, the lowering of price from the producers will initiate their higher use in other production branches (e.g., terrestrial animal or pets feeds). From the latter, it can be concluded that an action can be necessary but not adequate for achieving a solution to the problem; thus, the intended ethical result can be approached only through simultaneous or concomitant evaluations for other human acts.

These give us the next two characteristics that an ethical evaluation should have. It should be a holistic approach; to cover the possible counteractions and not to be limited only to the apparently obvious. Consequently, it should be comparative against the alternative actions and solutions and not to simply give an ethical load to one specific action. The request is not how ethical a solution is, but how ethical it is when compared to the other potential solutions. The latter, of course raises questions about what are considered as alternatives.

Alternatives can derive from scientific analysis and public rational dialogue between the involved parties. In the case of aquaculture-related ethical issues, alternatives can be different aquaculture practices, different forms of aquaculture, or even uses of the aquatic ecosystems other than aquaculture.

The second example that will be used as a tool, refers to the fish killing methodology and its welfare impacts. The mechanical stunning, for instance, is a good and humane method, but is technically not applicable in cases of smaller commercialized fish when individual killing can not take place (Poli et al. 2005). Although electro-stunning seem to be a humane method for most of the fish species and is largely proposed, there are cases that custom electricity currents are insufficient and result to slow killing and produce significant stress, like the eel that requires a much larger stunning current (European Food Safety Authority (EFSA) 2009a). There are also cases that electro-stunning will have certain impacts on carcass quality, like the absence of rigor mortis in sea bass, that may significantly affect the commercialization of fish (Knowles et al. 2007). The latter, in combination with technical problems in the application of the technique, and the costs can lead to significant impacts to the producers welfare. These individual problems can not be ethically solved by adopting one rigid stance and by insisting on one best solution. The species-specificities with regard to the killing methods has been also well understood by the responsible bodies, like the European Food Safety Authority (EFSA) that proposed different processes for humane killing in different fish (European Food Safety Authority (EFSA) 2009a, b, c, d, e, f, g). Conclusively, the other characteristic that an ethical evaluation should have is to take into account case specificities that may be radical in respect to the ethical load that a solution will give.

Taking a further step, in a continuously changing sector, as aquaculture, with rapid development, also the knowledge and technology change very quickly. Since the ethical evaluation is based on scientific elements, it should have an additional characteristic: to be flexible enough to incorporate new knowledge and to make changes if these are justified from the new knowledge/technology. For instance during the last years the technological development from wooden and metal sea cages to synthetic material ones, and subsequently the invention of the submersible cages have changed a lot in aspects of fish escaping risks and the subsequences; the more rationalized use of feeds during the recent years (Grigorakis 2007) and the parallel improvement in feeds and feeding techniques in order to meet the nutritional demands of cultured fish species have changed respective data (feed wastes, raw material demands, animal welfare, producers welfare etc.)

Conclusions

It was shown that a scheme based on the Food Ethics Council "matrix," but distinguishing the various production stages can be a useful tool for detailed assessment of ethical issues raised in aquaculture. This scheme is mainly focused in intensive cage-culture of carnivorous fish species, but can also cover the other forms of aquaculture in their ethical issues.

The ethical evaluation will be rather a utilitarian calculus of the benefits and the objections projected.

Examples of dilemmas from aquaculture practice and their potential solutions can provide a solid ground for examination of the required characteristics for an ethically accepted evaluation. The ethical evaluation should incorporate the ethical factor instead of being a purely scientific analysis, it should be holistic, should be comparable to available alternatives, and should have the flexibility to incorporate new knowledge and recalculate the ethical load under the new perspectives.

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